VOL. III. PART IV.

THE

INDIAN FOREST RECORDS

Note on the Preparation of Tannin Extracts

With special reference to those prepared from the bark of Mangrove (*Rhizophora mucronata*)

BY

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Photo. by R. S. Troup

Photo.-Engraved & printed at the Offices of the Survey of India, Calcutta 1911.

Teak tree height 152 ft., girth 10 ft. 3 in., height of bole 93 ft. Mohnyin Reserve. Katha, Upper Burma.

[*Frontispiece.*]

THE INDIAN FOREST RECORDS.

Vol. III] 1911 [Part I

A Note on Some Statistical and other Information regarding the Teak Forests of Burma.

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INTRODUCTION.

WORKING-PLANS operations commenced in Burma in December 1883, the forest dealt with being the Thonzè reserve in the Tharrawaddy Division. The working-plan, which was prepared by Mr. J. W. Oliver, was completed in June 1884. Since then working-plans operations in the teak forests of Burma have proceeded steadily, and up to the end of June 1910, 44 working-plans for forests containing teak have been sanctioned. As may be imagined, these working-plans are mines of information, and the main object of this paper is to present in convenient form the gist of this information, containing as it does many important facts regarding the constitution of the natural teak forests of Burma, the rate of growth of teak, statistics of outturn and other matters.

It should be noted that nothing but *natural* teak forest is dealt with, as statistics regarding teak plantations must of necessity be treated quite separately; also the forests concerned are only those under working-plans, unless the contrary is mentioned, since other teak forests have as a rule not yet been sufficiently examined and reported on.

Acknowledgments are due to Mr. J. H. Lace, Chief Conservator of Forests, Burma, for having kindly furnished some excellent photographs of types of teak forest, two of which (Plates II and III) are reproduced in this publication. Acknowledgments are also due to Mr. J. W. Oliver, late Conservator of Forests in Burma, for Plate IV, taken from a photograph of his in the collection of the Imperial Forest Research Institute, Dehra Dun.

CHAPTER I.

Distribution of Teak and Area of Teak Forests in Burma.

1. GEOGRAPHICAL DISTRIBUTION OF TEAK.

The northern limit of teak in Burma lies about 25° 30′ N. lat., that is, some distance out of the tropics ; the southern limit is in the Amherst District between 15° and 16° N. lat. ; on the east teak extends beyond the frontiers of the Province, while on the west it does not extend beyond the western watershed of the Irrawaddy and Chindwin rivers.

2. AREA STATISTICS.

Total area of teak forest.—It is impossible to estimate even approximately the total area of teak forest in Burma, because a considerable proportion lies outside the limits of reserved forests. Reservation is still proceeding actively, but is by no means completed yet : it may, indeed, be some years before even an approximate estimate of the total area of teak forest in Burma can be formed.

Area of reserves and of forests under working-plans.—The total area of reserved forests in Burma on the 30th June 1910 was 25,691 square miles. The total area under sanctioned working-plans on the same date was according to the official returns, 7,279 square miles ;* the great bulk of this total area represents teak-bearing forest.

Area of forests in respect of which the present statistics have been compiled.—The following is a summary of the areas for which the present statistics are compiled :—

Forests containing teak, for which working-plans have been prepared.

Particulars.	AREA IN SQUARE MILES.	
	Teak-bearing forest only.	Total area under working-plans.
(1) Forest in which the growing stock has been estimated by systematic valuation surveys over not less than 5 per cent. of the teak-bearing area.	5,574·3	6,179·2
(2) Forest not included under (1), *viz.* :—		
(i) Taungdwin reserve (Myittha Division), where the growing-stock was not estimated.	141·6	276·2
(ii) Taungdwingyi reserves (Minbu Division), where enumerations extended over only a little more than 1 per cent. of the teak-bearing area.	292·2	398·8
(iii) Madaya reserves (Mandalay Division), where no enumerations were carried out.	97	388·5
TOTAL .	6,105·1	7,242·7

* This includes forests other than those containing teak.

In forest classed under (1) above, enumerations have actually been carried out over 1,429·3 square miles, representing 23·1 per cent. of the total area, or 25·6 per cent. of the teak-bearing area.

Details of areas of the forests in question, with other particulars, will be found in Appendix I, and the situations of the forests are shown on the map.

Alterations in area.—In the case of some working-plans the areas given in the plans have subsequently been altered, owing to re-computation or other causes. In all such cases the original areas, as given in the working-plans, have been retained, as it is on these that the estimates of growing-stock detailed below have been based. This will explain any discrepancies between figures given in this publication and those which appear in official reports.

CHAPTER II.

Chief Types of Teak Forest.

1. General.

Reason for indicating chief types of forest.

A description of all the various types of teak forest in Burma is beyond the scope of this paper. The sole object in referring to the subject here is to give a brief indication of the main types of teak forest which constitute the great bulk of the areas under working-plans.

For working-plans purposes the distinction between "moist" and "dry" teak forest is an important one, in that the exploitable size in the latter is frequently less than it is in the former. It is therefore justifiable here to make some allusion to the main types of teak forest.

Classification difficult.

The classification of the teak forests of Burma into their main types and sub-types has always proved a difficult matter. Brandis in his Report on the Attaran Forests* divided the teak localities in the upper mixed forests of Lower Burma alone into no fewer than six groups, to which we might add several more if we included the various sub-types met with in Upper Burma. Kurz in his Preliminary Report on the Forest Vegetation of Pegu,† draws attention to the wide distribution of teak over the various classes of deciduous forests in the following sentence: "Teak and *pyinkado* (*Xylia dolabriformis*) are of very little value in the determination of various kinds of forests, for the simple reason that they occur in all sorts of leaf-shedding forests. In fact they are really missed only in the littoral and swamp forests."

Upper and lower mixed.

We are concerned here mainly with those teak forests which have been examined in connection with working-plans operations, but as they represent a considerable proportion of the most valuable teak forests in Burma they may be taken as fairly typical. There is little difficulty in dividing these forests into two main classes :—

I. Upper mixed.—(*Vide* Plate II.)
II. Lower mixed.—(*Vide* Plate III.)

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* Brandis, Report on the Attaran Forests, 1860, p. 51.

† Kurz, Preliminary Report on the Forest and other Vegetation of Pegu, 1875, p. 63.

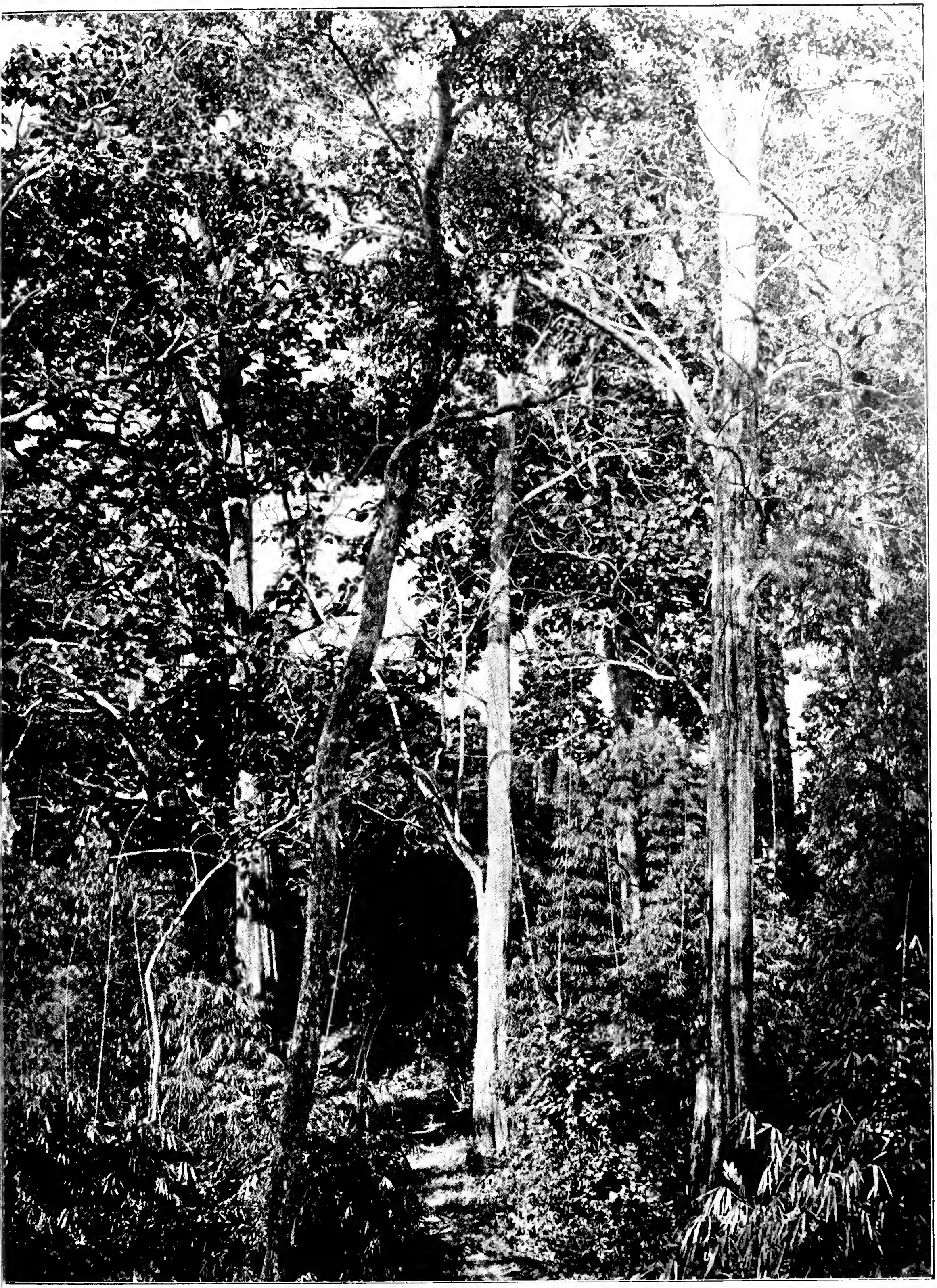
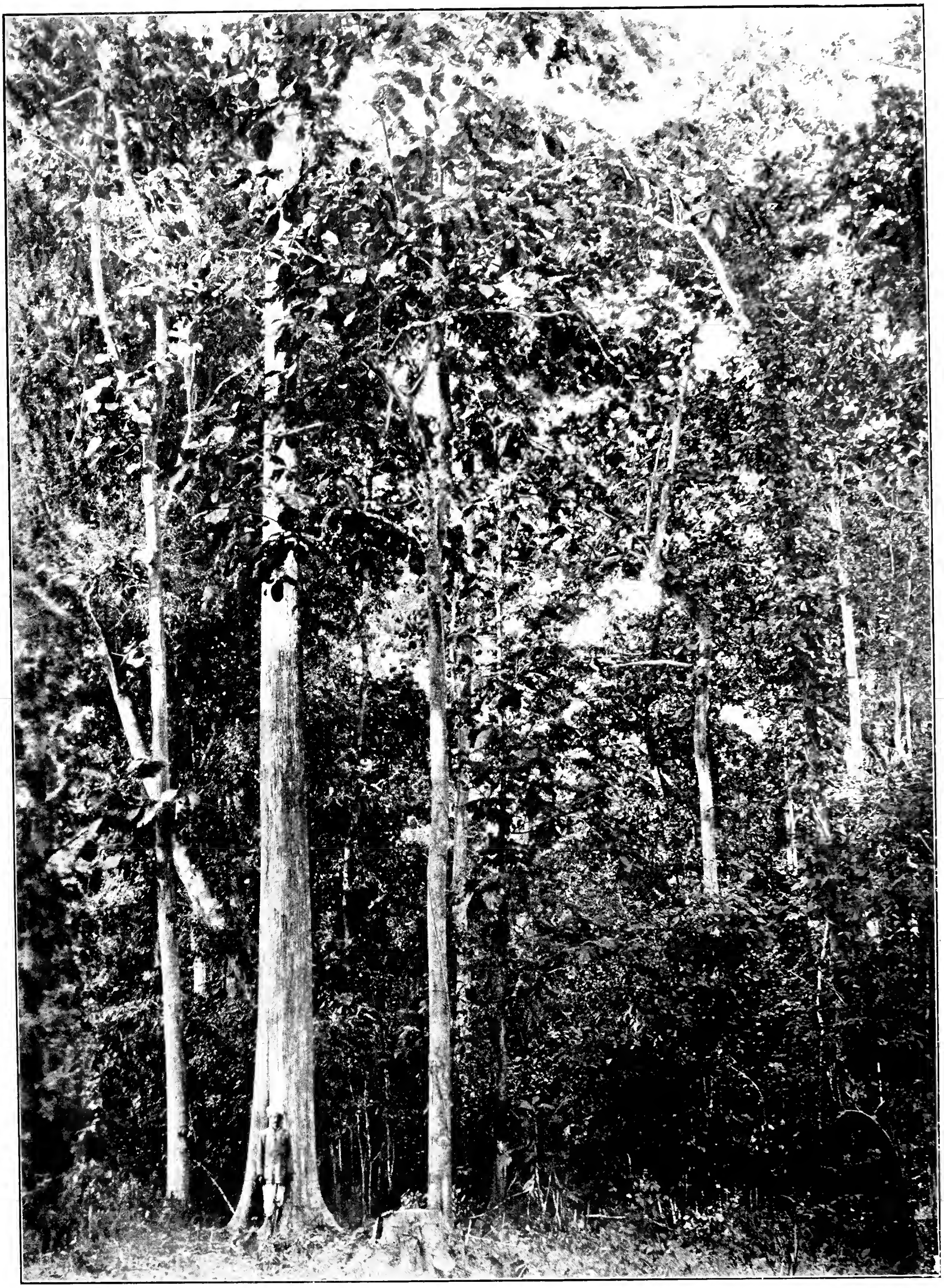


Photo. by J. H. Lace.

Teak in upper mixed forest with *Cephalostachyum pergracile*, Bhamo Division, Upper Burma. Girdled teak tree in centre, and green teak trees on right and left: tree on right 11 ft. 9 in. in girth.

[*To face page 4.*]



Lower mixed forest, Saing Yanè Reserve, Toungoo Division. Teak tree with man at base: *Dillenia* tree to right.

[*To face page 5*]

Of these the upper mixed is by far the more extensive and may be said to be the home of teak *par excellence :* some of the richest teak areas, however, are to be found in lower mixed forest.

It is to be understood that both these types are essentially deciduous, but they tend to merge into evergreen in their moister parts, while the two types themselves sometimes merge imperceptibly into each other, so that the line between upper and lower mixed forest is not always a sharp one.

The general distinction between the two classes may be said to be as follows :—

(1) *Upper mixed* forest typically occupies hilly country, and is usually characterised by the prevalence of bamboos.

(2) *Lower mixed* forest occurs on land which is flat or nearly so, and is usually alluvial. Bamboos are either absent or not well distributed.

2. UPPER MIXED DECIDUOUS FORESTS.

I. Upper mixed. (*a*) Dry and (*b*) moist.

The upper mixed forests may be divided into two chief types—(*a*) *dry* and (*b*) *moist*, the distinction lying in the comparative dryness and moistness of the forest growth, of which the best indicators are the bamboos which form so important an element in the composition of the crop. It may be mentioned that the majority of the associates of teak extend both to the dry and to the moist upper mixed forests, and many are found also in the lower mixed forests : hence it is impossible to do more than enumerate a few of the more characteristic species in each.

(*a*) Dry upper mixed.

(*a*) *Dry forest.*—The most typical bamboo in the dry upper mixed forest, is *Dendrocalamus strictus*, but some of the bamboos of the moist forest, notably *Cephalostachyum pergracile*, extend, often in stunted form, to this type of forest. *Bambusa Tulda* occurs in dry as well as in moist forest, and *Thyrsostachys Oliveri* is found in fairly dry forest in Upper Burma. The distinction between dry and moist forest is for this reason very difficult to draw at times. Dry upper mixed forest may either occur in unbroken stretches of considerable extent, or may be confined to the crests and upper slopes of ridges or spurs, the lower slopes of which are occupied by moist forest. In dry mixed forest teak does not usually reach such large dimensions as in the moist forest, but as a rule

reproduces itself in greater abundance. The most typical associates of teak in this class of forest are *Xylia dolabriformis*, *Terminalia tomentosa*, *Acacia Catechu*, *Sterculia* spp., *Pterocarpus macrocarpus* (*padauk*), *Homalium tomentosum*, *Dalbergia cultrata*, and many others: on ridges are frequently found *thitya* (*Shorea obtusa*) and *ingyin* (*Pentacme suavis*), the forest then being conveniently designated "semi-*indaing*."

(b) Moist upper mixed.

(*b*) *Moist forest.*—The prevailing bamboos vary with locality. Throughout the forests of the Pegu Yoma and certain other tracts the typical bamboo of the moist mixed forest is *Bambusa polymorpha*, with *Cephalostachyum pergracile* in its more luxuriant form. In moister valleys *Dendrocalamus longispathus* is typically found. Elsewhere the bamboos vary, those in the northern parts of Upper Burma including *Dendrocalamus Brandisii*, *D. Hamiltonii*, *D. membranaceus*, and others. Where the moist forest merges into evergreen dense masses of *wathabut* bamboo (*Teinostachyum Helferi*) cover the ground.

Some of the commoner associates of teak in the moist upper mixed forests are *Xylia dolabriformis* (of large size), *Lagerstrœmia Flos-Reginæ*, *L. tomentosa*, *Anogeissus acuminata*, *Terminalia Chebula*, *T. pyrifolia*, *T. belerica*, *Homalium tomentosum*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Vitex glabrata*, *Eugenia* spp., and many others.

3. LOWER MIXED DECIDUOUS FORESTS.

II. Lower mixed.

As has been stated above, the lower mixed forests are characterised by the absence, or comparative scarcity, of bamboos. Teak is found only in the better drained areas, and its chief associates are *Xylia dolabriformis*, *Lagerstrœmia Flos-Reginæ*, *Homalium tomentosum*, *Dipterocarpus alatus*, *Berrya Ammonilla*, *Terminalia tomentosa*, *T. pyrifolia*, *T. belerica*, *T. Chebula*, *Adina cordifolia*, *A. sessilifolia*, *Stephegyne diversifolia*, *Odina Wodier*, *Spondias mangifera*, *Eugenia Jambolana*, *Eriolæna Candollei*, *Careya arborea*, *Vitex glabrata*, *Dillenia pentagyna*, *Miliusa velutina*, *Diospyros ehretioides*, *Kydia calycina*, *Pterospermum semi-sagittatum*, *Dalbergia cultrata*, *D. purpurea*, *Phyllanthus Emblica*, *Anogeissus acuminata*, *Briedelia retusa*, *Schleichera trijuga*, and many others.

4. OTHER TYPES.

Although most of the important teak forests in Burma may be brought under one of the types sketched above, there are other distinct types,

such as (1) Teak in *indaing* forest, (*i.e.*, mixed with *Dipterocarpus tuberculatus*), the teak being almost invariably stunted and of little importance, (2) Teak in evergreen forest (*vide* Plate IV), the teak trees often being of large size, with little or no reproduction, leading to the inference that the evergreen has encroached in a once deciduous forest, and ousted the teak, (3) Teak in "pockets" or "rivers," generally near water-courses, in a groundwork of *indaing* or other non-teak-bearing forest. Other types could be mentioned; of these one of the most important is the alluvial type with pure or nearly pure teak, commonly found in the bends of streams in upper or lower mixed forest: this type of teak forest, which occurs in patches, may well be classified for general purposes under the type of forest with which it is associated, and of which it is essentially the offspring. The most characteristic bamboo, where bamboos occur in such flats, is *Bambusa Tulda* (*vide* Plate V): very often, however, bamboos are absent.

Description of forests.

A general description of the different forests under working-plans in Burma would be beyond the scope of this paper. For the purpose of reference, however, a brief description of each of these forests is given in Appendix I.

CHAPTER III.

Statistics regarding the Growing-Stock and Yield of Various Teak Forests.

1. General.

Difficulty in comparing statistics of different working-plans.

An accurate comparison between the growing-stocks of the various teak forests of Burma, and a clear idea of what the proportion and density of teak in natural forests should be, is not such an easy matter as might be supposed, for the following reasons :—

(1) Most of the teak forests for which working-plans have been compiled have been heavily worked—in many cases much over-worked—in years past, and contain a smaller proportion of large-sized timber than they should normally contain : some forests, on the other hand, have escaped lightly.

(2) The classification adopted in different working-plans is not always the same. Thus some working-plans take no account of young teak, while others make no mention of unsound trees. These facts are perhaps hardly of very great importance, because the accurate enumeration of teak saplings and seedlings, particularly in the hot weather when they are leafless, is a most difficult matter, while as regards unsound trees, the distinction between these and sound trees is often a matter of mere speculation, particularly when left to Burmese enumerators and coolies.

2. Past Working in Teak Forests.

Turning to the question of timber working prior to the working-plans enumerations, the following facts may be noted with regard to the various forests hitherto examined :—

Forests of the Pegu Yoma.—The great majority of these forests have been heavily worked during past years. Before the annexation of Upper Burma in 1886, the Pyinmana and Taungdwingyi forests were in parts almost recklessly depleted of large-sized timber, while under-sized trees were also felled in considerable numbers. In Prome, Tharrawaddy and Rangoon a good deal of girdling was carried out from 1856 onwards, but not to the same wasteful extent as in Pyinmana. In Pegu,

Shwegyin and Toungoo a fair amount of girdling took place in the sixties and early seventies in some of the forests : there was, however, little or no working in the Bondaung, W. Swa, Sabyin and Lonyan reserves in the Toungoo Division.

Chindwin forests.—The more accessible localities were heavily worked before the annexation, and have been steadily worked since : this applies to the Kale and Mawku Working Circles, but a considerable portion of the Taungdwin forests have been little worked owing to their inaccessibility.

Ruby Mines forests.—These forests were very heavily worked before the annexation, only the more inaccessible localities escaping ; they have also been steadily worked since the British occupation.

Madaya forests, Mandalay.—These forests were recklessly overworked in Burmese times. No enumerations have been made under the working-plan, but if enumerations were carried out they would no doubt reveal a large number of teak stumps.

Mohnyin forest, Katha.—This forest, judging by the teak stumps enumerated in valuation surveys, was worked over to some extent prior to the working-plan, but the working does not appear to have been excessive.

Forests east of the Sittang.—The Ziyaing-Mehaw forests (Pyinmana) were in part worked over to a moderate extent prior to the enumerations, but part of the area was practically untouched. In the Gwethe forest, (Toungoo) a considerable amount of girdling was carried out from 1869 to 1873.

Plains forests of Zigôn, Tharrawaddy and Rangoon.—The Kangyi forest was not very heavily worked prior to the enumerations, while the Satpôk, Sitkwin and Thindawyo reserves were practically untouched so far as teak is concerned ; the same applies to the Rangoon plains forests.

Thaungyin forests.—A considerable amount of girdling and extraction had been carried out prior to the working-plans enumerations.

3. METHODS OF ESTIMATING THE GROWING-STOCK.

Sample-plots.

In the great majority of working-plans the growing-stock has been estimated from enumerations in sample-plots scattered over the area in representative types of forest. Generally these sample-plots are laid out in

teak-bearing forest only, the area of this forest being separately estimated and the total growing-stock in it being deduced accordingly. In most working-plans the area enumerated is roughly $\frac{1}{4}$ of the total area under consideration, but in some cases it is more or less : details are given in the last column of Appendix II.

Linear valuation surveys.

In a few cases linear valuation surveys have been adopted. Among the older working-plans this system was employed in the case of the Mohnyin reserve (Katha) and part of the Môkka reserve (Tharrawaddy). It has again come into prominence lately, in connection with the Taungdwin Reserve in the Myittha Division, and the Hintha Working Circle of the Ruby Mines Division, the main object being the compilation of working-plans with greater despatch than is possible where representative sample-plots have to be laid out.

Enumeration of the whole area.

In the case of two working-plans—those of the Kangyi reserve in the Zigôn Division (7·6 square miles), and the Satpôk, Sitkwin and Thindawyo reserves of the Tharrawaddy Division (20·7 square miles)—enumerations extended over the whole area. These reserves being on flat land, with few well-defined natural features, it was found more expeditious and less costly to enumerate the whole area than to mark out sample-plots.

4. Teak Growing-Stock over whole Forests.

(1) *General.*

Size of areas considered.

The proportion of teak in any piece of forest must necessarily depend on the extent of forest taken, for if small patches be chosen it would be possible to select groups of pure teak forest containing a much larger number of teak trees per acre than can ever be found over extensive areas. For our purpose the most practical method of procedure will be to consider the growing stock in teak-bearing forest over large areas, namely, whole working-circles.

Teak-bearing and non-teak-bearing forest.

The working-plans generally divide the tracts dealt with into "teak-bearing" and "non-teak-bearing" forest, the latter including blanks, river-beds, etc., as well as evergreen, *indaing* and other types of forest which bear no teak. Unfortunately the term "teak-

Pure teak forest, Mohnyin Reserve, Katha, Upper Burma. Tree in centre, with man at base. 135 ft. high, bole 93 ft., girth 11 ft. 4 inch.

[To face page 1

bearing " forest is itself a somewhat elastic term, for the teak may be found in isolated patches or single trees widely separated by forest of a similar type containing no teak, but the whole may nevertheless be classed as " teak-bearing " because it is more or less homogeneous and is of a type capable of producing teak. Again, as in the case of some of the plains forests—the Rangoon Plains forests, and the Tonkan and Thindawyo reserves, for example —the teak is found only in certain parts of the area, and yet " teak-bearing " forest is not separately classified because the forests are not considered primarily as teak forests.

Statistical information.

From what has just been stated, it will be seen that too strict a comparison between the statistics furnished by the various working-plans, so far as the teak growing-stock is concerned, is liable to be misleading. Statistics regarding the growing-stock of forests under working-plans are furnished in Appendix II, where the average teak growing-stock per 100 acres has been worked out for all the forests in which working-plans enumerations have been carried out.

(2) *Number of teak trees per unit of area.*

Richness of forest judged from three different points of view.

It will be convenient, for our purpose, to consider the richness of the various teak forests from three different points of view, namely, (*a*) Forests rich in large teak trees, (*b*) Forests rich in teak trees 3 feet in girth and over, and (*c*) Forests rich in small-sized teak, below 3 feet in girth. Perhaps the safest general criterion for judging the richness of teak forests is to consider the total number of sound trees 3 feet in girth and over per 100 acres, because the enumeration of smaller-sized trees, as mentioned above, is not usually reliable, while a comparison based on large trees only is unsafe, in that some forests, otherwise rich, have been depleted of a considerable proportion of their larger trees.

(*a*) *Forests rich in large-sized teak.*—Of all the teak forests in Burma of which the growing-stock has hitherto been estimated, the Mohnyin reserve in the Katha Division easily heads the list so far as richness in large trees is concerned. This reserve contains considerable stretches of practically pure teak forest in which the trees attain large dimensions; this type of forest is shown in Plate VI, while the Frontispiece shows one of the tallest teak trees met with in the reserve.

The following is a statement of the richest teak forests in which enumerations have hitherto been made :—

Reserves containing over 100 teak trees 6 feet in girth and over per 100 acres.

Order of richness.	Forest Division.	Reserve or Working Circle.	NUMBER OF TEAK TREES PER 100 ACRES OF TEAK-BEARING FOREST. 7 feet girth and over.	6 feet to 7 feet girth.	Total 6 feet girth and over.
1	Katha . .	Mohnyin .	Not separately estimated.		241
2	Toungoo . .	Bondaung .	108	63	171
3	Pyinmana .	Ziyaing-Mehaw	104	57	161
4	Zigôn . .	Bawbin . .	101	31	132
5	Tharrawaddy .	Satpôk . .	56	66	122
6	,, .	Minhla . .	86	35	121
7	,, .	Kadinbilin .	87	30	117
8	,, .	Kônbilin . .	88	24	112
	Zigôn . .	Kangyi . .	62	50	112
	,, . .	Gamôn . .	78	34	112
11	Upper Chindwin.	Mawku . .	67	40	107
12	Pyinmana .	Yeni . .	59	45	104
13	Zigôn . .	Taungnyo .	74	27	101

It will be seen from this statement that it is an exceptionally rich teak forest that contains an average of one first class tree (7 feet in girth and over) per acre for the whole teak-bearing area.

(*b*) *Forests rich in trees* 3 *feet in girth and over.*—If we consider the total number of sound trees 3 feet in girth and over per unit of area, it is

interesting to note that the three richest teak forests in Burma are situated on flat alluvial land where bamboos are scarce or absent. The three forests in question are :—

(1) Mohnyin Reserve, Katha Division .	. 707 trees per 100 acres.
(2) Satpôk Reserve, Tharrawaddy Division	. 455 trees per 100 acres.
(3) Kangyi Reserve, Zigôn Division .	. 441 trees per 100 acres.

Of the forests of the upper mixed type there are two with over 400 sound trees 3 feet in girth and over per 100 acres : these are :—

(1) Bondaung Reserve, Toungoo Division	. 409 trees.
(2) Kadinbilin „ Tharrawaddy Division	. 408 trees.

There are no fewer than 9 forests with totals of between 300 and 400 trees per 100 acres ; these are all situated in the Pegu Yoma except the Ziyaing-Mehaw reserves, and all are of the upper mixed type.

(*c*) *Forest rich in small-sized teak.*—As mentioned above, a very accurate comparison of the number of small-sized teak in different forests is not always possible, as so much depends on the season in which the enumerations were carried out. The figures in Appendix II, however, reveal one or two interesting facts. First, as regards the Pyinmana reserves of the Pegu Yoma : although the heavy over-working of the past has considerably depleted these reserves of large trees, it is to be noted that reproduction is springing up in profusion, aided no doubt by the openings made in the overwood, the constant breaking down of bamboos by innumerable elephants, and the wounding of the soil during extraction. The figures, indeed, show that in the eight reserves concerned in no case is the crop of young teak under 3 feet in girth less than 768 plants per 100 acres : in only two other reserves in the Province is that number exceeded, namely in Bondaung reserve (799) and Kangyi reserve (2,920).

In these same Pyinmana reserves it is to be noted that the quantity of small teak in the drier forests of the north, particularly in the Sinthe reserve, is greater than it is in the moister reserves in the southern half of the Division ; this merely bears out the well-known fact that in the drier and therefore opener teak forests reproduction ordinarily springs up in greater profusion than in the moister and denser forests.

The profusion with which reproduction is springing up in the Kangyi reserve is remarkable ; this is to be contrasted with the state of affairs in the Mohnyin reserve, where reproduction is very poor in comparison, although these two reserves resemble each other in being both situated on alluvial land and being both exceptionally rich in large-sized teak.

(3) *Percentage of teak in total growing-stock.*

In most of the existing working-plans the enumeration of species other than teak has been carried out with respect to trees 3 feet in girth and over. It is therefore possible to form an estimate of the percentage of teak in the whole growing-stock. In the Mohnyin reserve nothing but teak was enumerated, and hence it is impossible to estimate its relative abundance as compared with the aggregate of all species : otherwise it is probable that the percentage of teak would be found to be higher than in any other forest hitherto enumerated.

Of the forests in which all species were enumerated the following contain the greatest percentage of teak in forest classed as " teak-bearing " :—

Order of richness.	Forest Division.	Name of Forest.	Percentage of sound teak trees 3 feet in girth and over in total growing stock of all species of the same dimensions.
1	Zigôn	Bawbin	33
2	,, ...	Kangyi	29
3	Toungoo . . .	Bondaung . . .	21
4	Pyinmana . . .	Ngalaik	20
5	Zigôn	Taungnyo . . .	19
	,, ...	Gamôn	
	Tharrawaddy . .	Kadinbilin . . .	
8	,, ...	Kônbilin	17
	,, ...	Thônzè	
10	,, ...	Satpôk	16
	Prome . . .	Nawin	
12	Thayetmyo . . .	East Yoma, Satsuwa and Tindaw.	15

All the other forests hitherto enumerated have less than 15 per cent. of teak in their composition. The lowest proportion of teak in true teak reserves hitherto enumerated is 6 per cent., in the Gwethe and Saing working circles of the Toungoo Division. There are, it is true, certain plains forests with a lower percentage, namely, Thindawyo (5 per cent.), Tonkan (2 per cent.), and the Rangoon Plains forests (1 per cent.) : these forests, however, were reserved for the supply not of teak, but of miscellaneous species, and cannot be classed as teak reserves.

(4) *Relative proportion of teak of different age-classes.*

Taking the average of all reserves in which all five girth classes of teak have been fully enumerated, we find, as a general average for the whole of Burma, that the percentage of teak in each girth class is as follows :—

I. 7 feet girth and over	7	per cent.
II. 6 feet to 7 feet in girth	5	,,
III. 4½ to 6 feet in girth	10	,,
IV. 3 to 4½ feet in girth	17	,,
V. Under 3 feet in girth	61	,,
	100	

A reference to Appendix II will show that the proportions in the various reserves differ very widely from this average, and it is no doubt an open question whether the general average truly represents the state of affairs which should exist in a normal teak forest. It forms, however, some basis of comparison between the several reserves dealt with : for example, the deficiency of large trees and the excess of small trees in the Pegu Yoma forests of the Pyinmana Division are strikingly illustrated in this way.

(5) *Teak growing-stock in specially rich sample-plots.**

The query, "What constitutes rich natural teak forest ?" is best met by the reply that it depends entirely on the area in question. We have dealt hitherto with large forest tracts, running in some cases to hundreds of square miles, and have considered the information furnished

* In this section the term sample-plot is taken to include linear valuation surveys.

regarding the growing-stock of each by existing working-plans. We may now confine our attention to smaller areas, namely, the sample-plots over which working-plans enumerations have been carried out : these seldom reach 200 acres in extent, and ordinarily run to about 50 –100 acres, many being under 50 acres in extent. Here again we cannot depend on obtaining figures showing the maximum richness of natural teak forest, because these sample-plots are selected as far as possible to represent an average of the growing stock of the forests in the neighbourhood, and are not specially selected for their richness. In the absence of better statistics, however, we may examine a few of the richest sample-plots hitherto recorded, considering separately (*a*) areas rich in large-sized trees, (*b*) areas rich in teak trees of 3 feet girth and over and (*c*) areas rich in trees under 3 feet in girth.

(*a*) *Sample-plots rich in large-sized teak.*—The table below gives a list of sample-plots having an average of 5 or more *sound* teak trees 6 feet in girth and over per acre.

Statement of sample-plots rich in large-sized sound teak trees.

Order of richness in sound teak.	Forest Division.	Name of Forest.	Compartment and valuation survey No.	Area of sample-plot.	NUMBER OF TEAK TREES PER 100 ACRES. SOUND. I 7 feet and over.	II 6 feet to 7 feet.	Total 6 feet and over.	Sound and unsound 6 feet and over.
1	Zigôn . .	Taungnyo .	62 I	52	689	134	823	*
2	Toungoo .	Bondaung .	21 II	42	410	314	724	*
3	Zigôn . .	Bawbin .	64 II	44	390	190	580	*
4	Katha . .	Mohnyin .	3 Mo.	73·8	..	..	535	866
5	Tharrawaddy .	Thônzè .	4 I	13	391	140	531	*
6	Katha . .	Mohnyin .	6 Mo.	115	..	..	515	656

* Unsound trees of this size are not shown separately, but are almost negligible as the total number of unsound trees of all classes is small in each case.

There are altogether 14 recorded sample-plots having 4 or more sound teak trees 6 feet in girth and over to the acre, 12 plots having from 3 to

4 such trees to the acre, and a considerable number having from 2 to 3 to the acre : this, however, does not include sample-plots in which sound and unsound trees were not discriminated, as in the Mawku Working Circle.

(*b*) *Sample-plots rich in teak of all sizes from 3 feet girth upwards.*—There are 17 sample-plots recorded in the working-plans in which sound teak trees of all sizes from 3 feet in girth upwards number more than 10 trees to the acre, and 7 plots in which they number more than 15 to the acre. The latter are as follows :—

Statement of sample-plots rich in teak, 3 feet in girth and over.

Order of richness in sound trees.	Forest Division.	Name of Forest.	Compartment and valuation survey No.	Area of sample plot.	NUMBER OF TEAK TREES 3 FEET IN GIRTH AND OVER PER 100 ACRES.	
					Sound.	Sound and unsound.
				Acres.		
1	Katha . .	Mohnyin .	16 Mo.	20·4	3,275	5,560
2	Zigôn . .	Bawbin .	64 II.	44	1,818	1,870
3	Toungoo .	Bondaung .	21 II.	42	1,626	1,721
4	Zigôn . .	Taungnyo .	62 I.	52	1,598	1,637
5	Katha . .	Mohnyin .	5 Mo.	19·3	1,584	2,315
6	,, . .	,, .	12 Mo.	15·6	1,526	3,470
7	,, . .	,, .	19 Mo.	23	1,517	2,121

It may be noted that in none of the Pyinmana reserves of the Pegu Yoma does the number of teak trees 3 feet in girth and over exceed 603 sound or 650 sound and unsound trees per 100 acres in any sample-plot : the plot containing this number is 11 III of Yeni reserve (area 70·1 acres).

(*c*) *Sample-plots rich in teak under 3 feet in girth.*—The following statement contains a list of sample-plots having over 40 sound teak plants under 3 feet in girth to the acre :—

Statement of sample-plots rich in natural reproduction.

Order in richness.	Forest Division.	Name of Forest.	Compartment and valuation survey No.	Area of sample plot.	Number of sound teak under 3 feet in girth per 100 acres.
				Acres.	
1	Pyinmana .	Sinthe . .	23 I	37·6	7,292
2	,, .	Pozaungdaung .	18 I	21·7	6,959
3	,, .	Sinthe . .	27 I	68·2	5,192
4	,, .	,, . .	27 III	77	5,088
5	,, .	,, . .	29 I	77·2	4,827
6	,, .	,, . .	22 II	64·8	4,648
7	,, .	,, . .	12 III	83·2	4,569
8	,, .	,, . .	33 I	78·4	4,533
9	,, .	,, . .	19 I	73·2	4,496
10	Toungoo .	Pyuchaung .	26 III	76	4,196
11	Pyinmana .	Yanaungmyin	12 II	72·8	4,193
12	Toungoo .	Pyuchaung .	19 IV	87·2	4,176

It is noticeable here that the Pyinmana forests, although they show no sample-plots exceptionally rich in teak of the larger sizes, easily head the list of areas rich in natural reproduction. The Sinthe reserve, which contains so may such areas, is of a drier type than is usually met with in the teak forests of Burma.

CHAPTER IV.

Rate of Growth and Exploitable Age of Teak.

1. GENERAL.

Tabulated results.

In Appendix III will be found the tabulated results of all working-plans figures showing rate of growth up to 7 feet in girth, together with the exploitable age and girth limit, in different localities.

Rate of growth how ascertained.

In the earlier teak working-plans the use of Pressler's borer for ascertaining the rate of growth of teak was much more general than it is at the present time. This instrument, in fact, has of late years been discarded almost entirely, as it has not been found to give accurate results. At the present time the rate of growth is as a rule ascertained only by counting rings on stumps, and there can be no doubt that in consequence of this the figures deduced in the later working-plans are more accurate than those of the earlier plans where Pressler's borer was largely employed.

Reduction to same basis.

In the various working-plans the general custom has been to add 10 years to the age of a teak tree, as representing the approximate time required for a seedling to establish itself : in many cases, however, no such addition has been made, while in one case 15 years has been added. In order to be of any value for purposes of comparison, the figures for each working-plan must be reduced to the same basis, and for this reason the figures showing the average ages of trees of different girths have been made out on the assumption that nothing has been added to allow for a seedling to establish itself, *i.e.*, the countings all commence from 0 year and not from 10 or 15 years.

In some of the older working-plans diameter and not girth measurements have been recorded : in all such cases the ages have been corrected to correspond with the usually recognised girth classes.

Thickness of bark.

Again, it has not been the rule in these countings to allow for bark, and hence the figures given do not take the thickness of bark into account except in the case of the Mawku working circle.

Exploitable age and girth.

The figures for exploitable age (rotation) and girth in Appendix III are those actually given in the working-plans, that is, after allowing for thickness of bark and for the time taken for a seedling to establish itself. As a general rule the exploitable girth limit in Burma has been fixed at 7 feet, with a reduction to 6 feet in the case of poor localities where teak does not reach large size. It is, however, a question whether the exploitable girth should not be raised in certain accessible localities where sound teak of large dimensions can be grown.

With a very few exceptions the exploitable age, for a girth of 7 feet, has been fixed at 150 to 180 years, that is, allowing for the establishment of the seedling and other contingencies. The only exceptions are to be found in the Kangyi and the Satpôk, Sitkwin and Thindawyo reserves (120 years each), the Kyaukmasin reserve (196 years) and the Ziyaing-Mehaw reserves (200 years). These are referred to again below.

2. STATISTICS REGARDING RATE OF GROWTH IN GIRTH.

(1) *Growth up to 7 feet in girth.*

Averages.

The average rate of growth in girth of natural teak for the whole of Burma, and a few of the fastest and slowest average rates of growth respectively for separate forests, are as follows :—

PARTICULARS.	AGE AND MEAN ANNUAL GIRTH INCREMENT (IN INCHES) FOR GIRTH OF							
	3′ 0″		4′ 6″		6′ 0″		7′ 0″	
	Age.	Mean annual increment.	Age.	Mean annual increment.	Age.	Mean annual increment.	Age.	Mean annual increment.
Average for whole of Burma	58	·621	90	·600	130	·554	155	·542
FASTEST GROWTH (AVERAGE FOR WHOLE FOREST).								
Kangyi	50	·720	65	·831	85	·847	110	·764
Satpôk, Sitkwin and Thindawyo	50	·720	70	·771	90	·800	110	·764
SLOWEST GROWTH (AVERAGE FOR WHOLE FOREST).								
Minbyin (dry forest only)	78	·461	116	·466	161	·447	186	·452
Kyaukmasin	75	·480	114	·474	155	·465	186	·452
Ziyaing and Mehaw	62	·581	112	·482	153	·471	190	·442
Pozaungdaung (dry forest only)	69	·522	110	·491	165	·436	..	..
Hintha Working Circle	64	·562	108	·500	152	·474	189	·444

As far as individual trees go, the following are the maximum and minimum rates of growth recorded:—

Maximum and minimum rate of growth.

PARTICULARS.	AGE FOR GIRTH OF				Mean annual girth increment (inches).	REMARKS.
	3′ 0″	4′ 6″	6′ 0″	7′ 0″		
MAXIMUM.						
Ngalaik Reserve, Pyinmana Division, compartment No. 19	14	23	30	42	2·00	Alluvial land : no bamboos.
MINIMUM.						
Sinthe Reserve, Pyinmana Division, compartment No. 45 .	163	211	300	357	·240	Spur, loam : bamboo *Dendrocalamus strictus*.

A stump showing slower growth than the minimum above-mentioned is recorded in compartment 78 of Minbyin reserve, where an age of 332 years corresponds to a girth of 6 feet 5 inches, representing a mean annual girth increment of ·232 inches, and giving an equivalent age of 362 years for a girth of 7 feet : this stump, however, was that of an injured tree, and the figures cannot therefore be accepted as representative.

Unfortunately many of the working-plans contain no reliable figures showing the girth increment of individual trees, so that the above maximum and minimum figures for individual trees are not based on *data* obtained from all working-plans. Figures obtained by Pressler's borer, for instance, are of no use so far as the whole life of a tree is concerned.

(2) *Growth above 7 feet in girth.*

Figures showing rate of growth of teak trees over 7 feet in girth are available only from a few working-plans, namely, up to 12 feet for Yeni, Yônbin and Yanaungmyin up to 11 feet for East Yoma, up to 10 feet for Minbyin, up to 9 feet for Kale, and up to 8 feet for Rangoon Hills, South Zamayi and Lower Thaungyin. A combination of the results

obtained, reduced to the average 7 feet basis (155 years), is as follows :—

Girth.	Transition period (years).	Corresponding age in years.	
		From actual statistics.	After rounding off to 25 years transition period.
7 feet		155	155
	24		
8 "		179	180
	25		
9 "		204	205
	24		
10 "		228	230
	20		
11 "		248	255
	26		
12 "		274	280
Average .	24		

Up to 10 feet in girth the figures may be taken as fairly representative, but above that the number of stumps on which countings were made is hardly sufficient to give reliable figures.

(3) *Diagram showing rates of growth in girth.*

The diagram on plate VII shows at a glance the rate of growth in girth of teak trees, as follows :—

(1) The fastest recorded growth of an individual tree.

(2) The fastest average growth for a whole forest (Kangyi reserve).

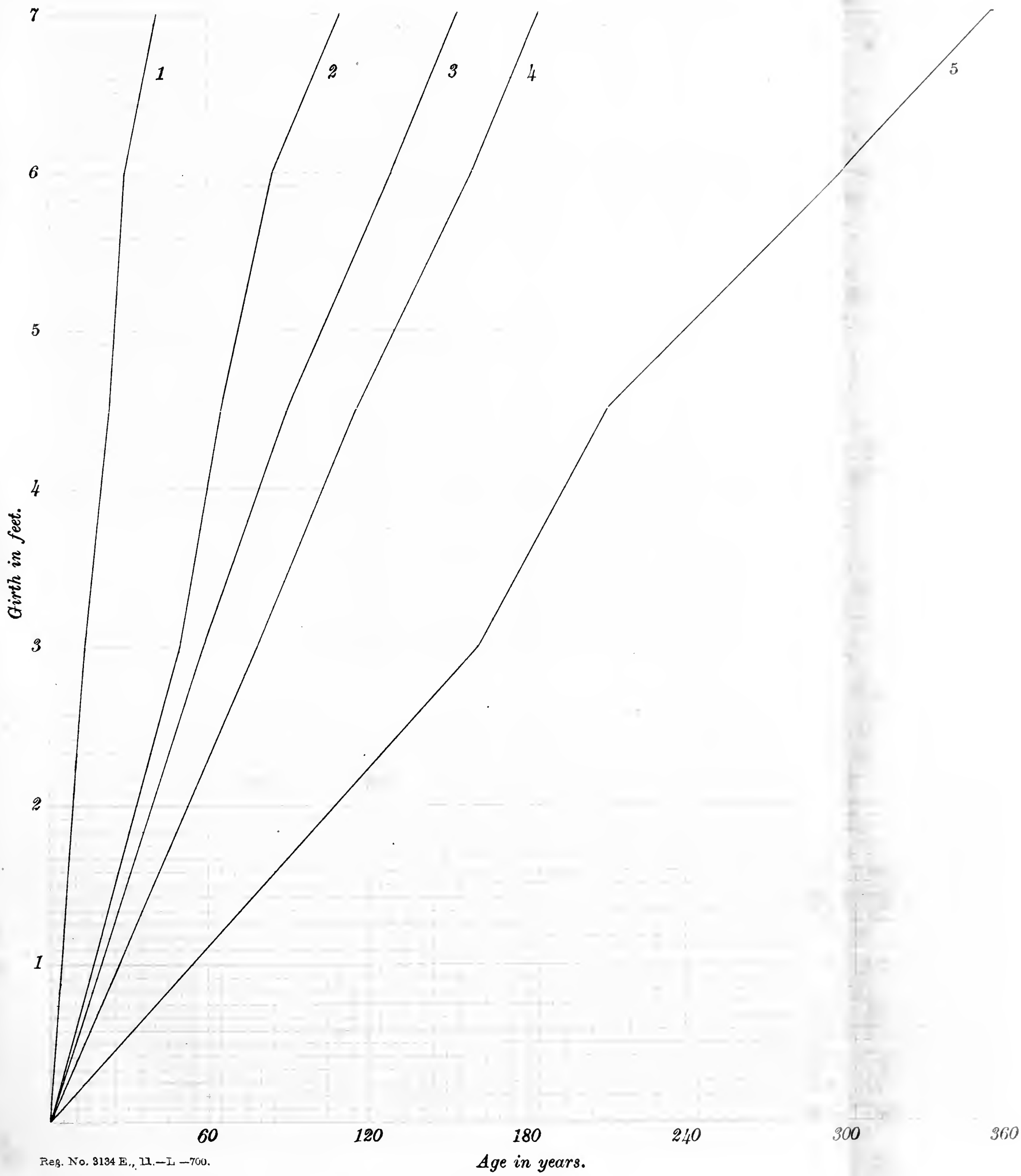
(3) The average growth for the whole of Burma.

(4) An example of one of the slowest average rates of growth for whole forests (Minbyin reserve, dry forest only).

(5) The slowest recorded growth of an individual tree.

 Plate VII.

Diagram showing different rates of growth in girth of teak.



Reg. No. 3134 E., 11.—L —700.

1. Fastest recorded rate of growth in an individual tree.
2. Do. do. of a whole forest (average for Kangyi reserve).
3. Average rate of growth for the whole of Burma.
4. Example of slow rate of growth for whole forest (average for Minbyin reserve, dry forest only).
5. Slowest recorded rate of growth in an individual tree.

[To face

Diagram showing different rates of growth in girth of teak.

Plate VII.

Reg. No. 3134 E., 11 —L —700.

1. Fastest recorded rate of growth in an individual tree.
2. Do. do. of a whole forest (average for Kangyi reserve).
3. Average rate of growth for the whole of Burma.
4. Example of slow rate of growth for whole forest (average for Minbyin reserve, dry forest only).
5. Slowest recorded rate of growth in an individual tree.

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It should be noted that no allowance has been made for the time taken for a seedling to establish itself, or for the thickness of bark.

3. INFLUENCE OF CERTAIN FACTORS ON THE RATE OF GROWTH.

We may now proceed to the consideration of a few miscellaneous facts brought out in existing working-plans, in so far as they concern the rate of growth.

(1) *Rate of growth in dry and in moist forest.*

The fact that most trees grow faster on rich than on poor soil hardly requires any demonstration. There are, however, certain interesting comparisons to be drawn from the *data* afforded by the working-plans, which we may deal with briefly.

Kyaukmasin Reserve.

The Kyaukmasin reserve, referred to on page 20, is situated in the Pegu Yoma, and is surrounded by other reserves in which the exploitable age fixed is never higher than 180 years, while that of the Kyaukmasin reserve is fixed at 196 years : at first sight, therefore, it appears somewhat strange that the rate of growth in the Kyaukmasin reserve should be so much slower than in the surrounding reserves. The slow rate of growth, however, is explained by the fact that teak is there found only on the ridges and upper slopes, and never low down in the moister regions of the streams. This explanation is corroborated by the fact that in this reserve the average age of a tree 7 feet in girth, without allowances for the establishment of the seedling, is identical with that recorded for the Minbyin reserve, on *poor* localities, namely, 186 years.

Ziyaing-Mehaw Reserves.

It has been mentioned above that the rate of growth in the Ziyaing-Mehaw reserves of the Pyinmana Division is exceptionally slow, the average age of a tree 7 feet in girth, without allowances, being reckoned at 190 years. These reserves are situated to the east of the Sittang river, quite apart from any of the other reserves in the Pyinmana Division, but not far from the Gwethe reserve in the Toungoo Division, of which they practically form a continuation. The rate of growth in Gwethe is considerably faster. But whereas a large proportion of the ring-countings in the Ziyaing-Mehaw reserves were carried out in dry

forest with *Dendrocalamus strictus* as the prevailing bamboo, forest of this type is absent in Gwethe, where *Bambusa polymorpha* is the chief bamboo in the teak areas, and the forest is considerably moister than in the Ziyaing-Mehaw reserves.

Considering the proximity of these reserves to each other, and the fact that both are situated on the same hill range and are similar in geological formation, the difference in rate of growth is striking, as the following statement shows :—

Reserve.	Average age of tree of girth of			
	3′	4′ 6″	6′	7′
Ziyaing-Mehaw	62	112	153	190
Gwethe	57	86	117	139

Some difference might perhaps be expected from the fact that in the case of the Gwethe reserve the figures were obtained chiefly, but not entirely, by Pressler's borer, whereas in the case of Ziyaing-Mehaw the counting of rings, on stumps was more largely carried out. This, however, cannot account for such a large difference, particularly as in Gwethe reserve the age of a tree 7 feet in girth as deduced from ring-countings corresponds exactly with the age as determined by borings. The difference is no doubt due largely to the fact that the Ziyaing-Mehaw forests are of a drier type than the Gwethe forest.

Exceptions to general rule.

Although the slower rate of growth and smaller size at maturity of teak trees grown on poor dry localities as compared with those grown on rich moist localities is almost axiomatic, this difference is not always so apparent in the younger age-classes. There are, in fact, one or two instances where the rate of growth is even faster in the drier than in the moister localities during the first half of the life of the tree : where this occurs, it is no doubt to be explained by the fact that in the richer localities teak suffers more from suppression during its earlier stages than in the poorer localities where the forest is more open.

Statistical examples.

The comparative rates of growth of teak trees in dry and moist forest are exemplified to a certain extent by the following figures abstracted from the working-plans :—

Rate of growth of teak trees in dry and in moist forest.

Forest Division.	Mame of Forest.	Average age of tree of girth of 3′	4′ 6″	6′	7′	Type of Forest.
Zigôn	Taungnyo	60	93	..	159	Moist.
		51	80	154	..	Dry.
Tharrawaddy	Thônzè	47	68	101	130	Moist.
		47	82	131	149	Dry.
,,	Môkka	..	..	..	137	Moist.
					165	Dry.
Pyinmana	Minbyin	59	86	124	149	Moist.
		78	116	161	186	Dry.
,,	Pozaungdaung	62	88	123	154	Moist.
		69	110	165	..	Dry.

(2) *Rapid growth on alluvial ground.*

Reference has been made on page 20 to the rapid growth of teak in the Kangyi, Satpôk, Sitkwin and Thindawyo reserves, the average age of a tree 7 feet in girth being 110 years in the case both of Kangyi and of the other three combined. These reserves are scattered on flat alluvial land on the plains of the Hlaing (Myitmaka) river, and although they are not far from the Pegu Yoma forests, the more rapid growth of teak on the flat alluvium as compared with the hill forests is most marked. It should be noted that the portions of these reserves where teak is found are generally well drained, although flat or nearly so.

The Kangyi reserve, like the Mohnyin reserve in the Katha Division, which is also situated on flat land, is capable of producing teak of very

large dimensions. The rate of growth in the Mohnyin reserve, however, is not so fast, the average age of a tree 7 feet in girth being 166 years (without allowances for the establishment of the seedling). It would appear from this fact that teak does not necessarily always show rapid growth on alluvial flat land.

With regard to small alluvial flats along the banks of streams in hilly country, the working-plans do not as a rule discriminate sufficiently between these localities and the surrounding hilly tracts to warrant any wide generalization, but such *data* as are available point as a rule to the fact that the rate of growth on these alluvial flats is faster than elsewhere. To quote a few examples : (1) In the Yeni reserve countings of rings were made on 343 stumps, the average annual girth increment being 0·524 inches : of these 26 stumps were on land described as level, without bamboos, and the average annual girth increment of these is 0·737 inches : (2) In the Minbyin reserve the mean annual girth increment of all stumps up to 7 feet in girth is 0·485 inches : of these 8 stumps were on flat alluvial land without bamboos, and these show a mean annual girth increment of 1·046 inches, that is, the rate of growth on the alluvial flats is more than twice as fast as it is elsewhere : (3) In the Ngalaik reserve the average age of 72 stumps at 7 feet girth is 140 years : of these 4 stumps were on flat alluvium, and these average 85 years at 7 feet girth. So far, then, the evidence available from existing working-plans generally tends to support the belief that if other conditions are equal, the rate of growth on alluvial flats is usually faster than it is elsewhere.

(3) *Influence of aspect on the rate of growth.*

During ring-countings and borings with Pressler's borer, the aspect of the slope on which these were made has been recorded in some working-plans. It was hoped that the compilation of the results might give some definite information regarding the effect of aspect on the rate of growth of teak. The information afforded, however, can hardly be regarded as entirely conclusive.

In compiling the figures given below only the results of ring-countings were taken, borings with Pressler's borer being entirely discarded as not giving sufficiently reliable results. This being so, the working-plans containing the required information are those of the Kale working circle in the Myittha Division (area 223 square miles) and the Yeni, Minbyin, Yanaungmyin Kaing and Palwé, Taungnyo, Pozaungdaung and Ngalaik reserves of the Pyinmana Division (total area 791 square miles). All the Pyinmana reserves, which are situated on the eastern slopes of the Pegu

Yoma, and which resemble each other topographically, have been grouped together, because the figures in each individual reserve are hardly sufficient to give reliable results.

The following table gives the results obtained with regard to the two forest tracts mentioned above :—

Order, as regards rate of growth.	KALE WORKING CIRCLE.			PYINMANA RESERVES.		
	Aspect.	Mean Annual girth increment (inches).	Number of stumps on which countings were made.	Aspect.	Mean Annual girth increment (inches).	Number of stumps on which countings were made.
1	N.	·510	32	N.	·568	48
2	S. W.	·479	24	S. E.	·557	33
3	W.	·477	36	N. E.	·541	26
4 and 5	N. W.	·463	40	E.	·534	49
	E.	·463	37	N. W.	·534	24
6	N. E.	·461	25	W.	·530	60
7	S.	·459	19	S. W.	·525	14
8	S. E.	·454	28	S.	·501	55

It will be seen that although the fastest growth takes place on northern aspects in both tracts and the slowest on general southerly aspects, there is not sufficient similarity between the results exhibited in the two tracts to afford any reason for generalizing.

It is noteworthy, however, that in the Kale Working Circle the fastest growth takes place on general northerly and westerly aspects, the easterly and southerly aspects showing slower growth. In the Pyinmana forests, on the other hand, the fastest growth takes place on northerly and easterly aspects, and the slowest on southerly and westerly aspects.

Although the geology of the two tracts is similar in general (sandstone with occasional beds of clay or conglomerate), they are totally different as far as topography is concerned. In the Kale working circle the main hill ranges run north and south, the strata dipping to the east, with the result that the western faces of the hills form steep escarpments and the

eastern slopes are more gentle. In the Pegu Yoma forests of Pyinmana, on the other hand, the strata dip at various angles and in different directions, with the result that the ridges and spurs ramify in all directions, the general trend of the central Pegu Yoma ridge being north and south and that of the main subsidiary ridges east and west.

So far as present information goes, therefore, the topography of the country and the local climatic conditions and other factors, appear to have so much influence on the rate of growth, that aspect must be regarded only as one of many factors which have to be reckoned with.

(4) *Variations in rate of growth.*

Considerable differences in the rate of growth of teak trees in the same locality are to be noticed almost universally, and as Mr. S. Carr remarks in the Minbyin working-plan with respect to the rate of growth, "Not only does it differ in different localities, but trees growing almost side by side frequently exhibit widely differing rates of growth. In such cases the difference must be due to causes other than the factors of the locality, such as fire, suppression, or injury from other causes."

In the teak forests of Burma suppression, whether by trees, bamboos, or climbers, is undoubtedly the most potent factor in causing this difference in the rate of growth of trees growing in similar localities, for a light-demanding species like the teak will stand little shade or interference with its crown, while it responds readily to any opening of the canopy, whether natural or artificial.

Mr. Carr has drawn attention, in the Yeni working-plan, to certain periodic interruptions in the rate of growth of teak, a phenomenon which is observable in many other localities. To quote Mr. Carr's own words : "For some cause or other which is not necessary to discuss here, the growth of a large proportion of the trees, as exhibited by the annual rings on stumps, has been very much retarded at several periods of their lives. The growth, after proceeding normally for a time, suddenly becomes abnormally slow, so much so that the rings are so close together as to be difficult, and in some cases impossible, to count with certainty. This period of slow girth would extend over a number of years and the growth would then again become normal. As many as four of these cycles of slow growth were noticed on some of the larger stumps, but the general number, where they existed at all, was two or three, and if they can be prevented altogether, it is obvious that in the future the age of a tree of 7 feet in girth will be considerably less than it has been in the past."

CHAPTER V.

Yield and Outturn of Teak Forests in Burma.

1. GENERAL.

The present chapter deals with the estimated yield of the various teak forests in Burma, as calculated in the working-plans, and the actual yield and outturn as recorded in the control forms. There are, however, a few preliminary matters to be considered regarding the manner in which the yield is fixed and the system of management under which the forests are worked.

System of Management.
(1) Selection.

With the three exceptions noted below, in all working-plans now in operation the system of management, so far as teak is concerned, is the selection system, this system being perhaps the only one which could be applied as a temporary means of working the large tracts of teak forest in Burma. The disadvantages attending this system, particularly as regards the conduct of operations for assisting natural reproduction and for encouraging the growth of teak against inferior species, have, of late, commanded a certain amount of attention, and in a revised working-plan for the Mohnyin reserve, which will come into operation shortly, the method of successive regeneration fellings will be introduced. This may be regarded as a preliminary step towards the introduction of more systematic methods of working the teak forests of Burma.

(2) Improvement fellings.

In the rough working-plans for the Taungdwingyi and Madaya forests, and in the working-plan of the Tonkan reserve, which can hardly be termed a teak forest, the system of working prescribed is improvement fellings in the interests of teak, no yield by number of trees being fixed.

Periods and sub-periods.

The periods of the teak working-plans vary from 20 to 40 years, with the exception of the Mohnyin working-plan hitherto in force, which has a period of 15 years, terminating in 1910. More than half the existing working-plans have periods of 30 years.

Annual coupes would be impracticable in the teak forests of Burma, because the collection of timber-dragging elephants and labour, and the organization of the work, is a large business, which could not be transferred from coupe to coupe each year. For this reason "sub-periodic" and not annual felling areas are prescribed, and the period of the

working-plan is divided into a number of "sub-periods" accordingly. These sub-periods vary from 4 to 8 years, but are usually 5 or 6 years, in duration.

Details of periods and sub-periods in the various working-plans will be found in Appendices I and III.

Girdling.

When teak trees are selected for felling they are at the same time "girdled," or ringed all round down to the heart-wood, the object being to kill them and render the timber sufficiently buoyant for floating purposes. Girdling also has the effect of seasoning the timber. Actual felling does not commence for 3 years after girdling. In the teak working-plans of Burma, therefore, instead of annual "felling statements" we find "sub-periodic girdling statements."

2. Estimates of Yield and Results of Working.

Yield how fixed.

In all the working-plans where the selection system is prescribed, the yield is estimated by the number of trees of exploitable size which may be girdled in each sub-period, the average annual yield being also stated. The sub-periodic areas, in which alone girdlings may be carried out in the corresponding sub-period, are also defined. The actual selection of trees for girdling is carried out under sylvicultural rules.

As a general rule the working-plans lay down that the sub-periodic yield by number of trees is to be regarded as strictly limiting the number of trees to be girdled during the sub-period, any excess girdling requiring special sanction. In the case of an under-estimate such a rigid fixing of the possibility, however, is apt to result in the leaving of over-mature trees which ought sylviculturally to be removed, and hence in some of the more recent working-plans the estimate of the yield is rightly regarded merely as a guide, and may be exceeded in moderation without special sanction, provided the necessary sylvicultural rules have been complied with.

Statistics regarding yield and outturn.

In Appendix IV will be found a summary of figures, compiled from working-plans and Control forms, relating to yield and outturn.

Accuracy of figures.

With regard to statistics relating to the results of working, it may be said generally that the figures relating to the actual number of trees girdled (column 8) are correct, as they are compiled from statements prepared by girdling officers. The figures relating to the number of logs and volume of

timber yielded (columns 10 to 15), so far as totals for Divisions go, are accurate in that they are based on actual statements prepared at measuring stations : in some cases, however, they are not to be relied on so far as distribution among the different working circles is concerned, because the hammer marks denoting the forests from which the logs came are not always taken into consideration in classifying the timber at its destination. It should in any case be noted that these figures do not include logs lost in transit, and in some of the floating streams this loss is considerable.

The figures relating to the number of trees felled (column 9) are not generally to be relied on, since they are as a rule based on the statements of wood-cutters.

Actuals compared with estimates.

Tendency to over-estimate.

It will be seen, on a comparison between columns 7 and 8 of Appendix IV, that the yield has in the majority of cases been overestimated. This does not necessarily imply that the estimate of the number of marketable trees on the ground is wrong ; for in many cases numbers of such trees have to be left unfelled for sylvicultural reasons, and as the number left depends largely on the idiosyncrasies of the girdling officer the number of trees actually girdled over a given area may vary considerably on that account alone.

The fact, however, remains that the tendency has been to over-estimate the number of teak trees which may be girdled during any sub-period. Strictly speaking the number of naturally dead trees should count against the yield. Where this is the case the estimate of trees to be felled is probably not too high in the majority of cases ; it is impossible, however, to be certain on this point, since, as mentioned above, the figures in column 9 are not to be relied on.

Yield per square mile.

(1) Mohnyin reserve.

The highest estimated yield per square mile* is in Mohnyin reserve, namely, an average of 45 trees of 7 feet girth per annum. In the two sub-periods already passed through, however, only some 24 trees per square mile per annum have been actually girdled, though if we accept the figures for trees actually felled (column 9) the 1st sub-period shows an average yield of 43 trees per square mile per annum. It may be remarked that enumerations in this reserve were carried out by means of linear valuation surveys extending over only 5·9 per cent. of the total area, so that a high degree of accuracy could not be expected.

* This means per square mile of total teak-bearing forest, and not per square mile actually worked over during the year.

In actual results, as well as in the estimate, the Mohnyin reserve shows a higher yield of teak per annum than any other working circle in Burma.

(2) Other high yields.

The following is a statement of working circles which have hitherto yielded 10 trees or over per square mile of teak-bearing forest per annum, the actual results for completed sub-periods being given alongside the working-plan estimates :—

Forest Division.	Name of Working Circle.	Percentage of area enumerated.	Estimated average yield by number of trees (girth 7 feet and over) per square mile of teak-bearing forest per annum.	Actual average number of trees girdled per square mile per annum in completed sub-periods to date.
Katha . .	Môhnyin . .	5·9 % of total area	45	24
Toungoo . .	Bondaung .	25 ,, ,, ,,	18	18
Tharrawaddy .	Kadinbilin .	18 ,, ,, ,,	16	16
Zigôn . .	Kangyi . .	Whole area .	16	16
,, . .	Gamôn . .	12·5 % of total area	14	12
,, . .	Bawbin . .	18·8 ,, ,, ,,	14	12
,, . .	Taungnyo .	24 ,, ,, ,,	12	12
Toungoo . .	Gwethe . .	34 ,, ,, ,,	12	11
Tharrawaddy .	Kônbilin .	22% of teak-bearing area.	13	10
Prome . .	S. & N. Nawin & Chaungzauk.	23·9% of total area	11	10
Tharrawaddy .	Satpôk . .	Whole area .	21	1st sub-period not yet completed.
Pyinmana .	Ziyaing-Mehaw	34 % of teak-bearing area.	21	
Myittha . .	Kale . .	27·5 ,, ,, ,,	17	
Upper Chindwin	Mawku . .	24 ,, ,, ,,	17	
Tharrawaddy .	Sitkwin . .	Whole area . .	15	

A comparison of the figures in cloumns 9 and 10 of Appendix IV should show the average number of logs yielded per tree, but as a matter of fact the figures are not to be relied on because those in column 9 are, as stated above, not always accurate, while those in column 10 do not allow for loss in transit.

Logs yielded per tree.

The average volume per log will be found in columns 14 and 15 of Appendix IV. The size of logs yielded must of necessity depend greatly on the facilities for extracting large timber, and not only on the size of the trees felled.

Average volume per log.

The largest average logs brought out so far in any one sub-period are the 639 logs extracted from the Kangyi reserve, Zigôn Division, during the sub-period 1902-03 to 1905-06, which averaged 103 cubic feet.

Large average logs.

The following statement gives the names of forests from which the largest average logs have hitherto been extracted, the averages being given by single sub-periods :—

Forest Division.	Working Circle.	Average volume per log of all teak logs extracted during a single sub-period.
		Cubic feet.
Zigôn	Kangyi	103
"	Taungnyo	92
"	"	90
"	Kangyi	79
"	Bawbin	73
"	Gamôn	72
Tharrawaddy	Kadinbilin	72
Prome	Shwele.	68
Toungoo	West Swa, Sabyin and Lonyan.	68
Prome	N. Nawin	67
"	S. Nawin	67
Zigôn	Bawbin	67
Tharrawaddy	Thônzè	67
Toungoo	Kabaung	67
"	"	66
Tharrawaddy	Minhla.	66
"	Môkka	66
Katha	Môhnyin	65

It is noteworthy that the great bulk of the larger sized timber extracted hitherto under the prescriptions of working-plans has come from the Myitmaka (Hlaing river) drainage, which includes the forests of the Zigôn and Tharrawaddy Divisions and the Shwele forests of the Prome Division. All this timber was extracted by Government agency. It may be mentioned that the present Zigôn Division until recently formed part of the Tharrawaddy Division and still forms the northern half of the Tharrawaddy Civil District.

Small size of Pyinmana timber.

The small size of the timber extracted from the Pyinmana forests under working-plans prescriptions (see Appendix IV, column 14) is explained by the fact that previous to the British occupation of Upper Burma these forests had been heavily overworked, and the quantity of large timber left for extraction during recent years has been comparatively small. The forests themselves, with the exception perhaps of the Sinthe reserve, are capable of producing timber of large size, and it is only a matter of time until the average volume of logs may be expected to increase to something approaching the standard of Zigôn, Tharrawaddy, and other Lower Burma Divisions.

Figures refer only to forests under regular working-plans.

The statistics given here naturally refer only to forests under working-plans, and do not include figures relating to the large areas of teak forests in Upper Burma which have hitherto been worked only under rough girdling schemes and for which the preparation of regular working-plans has been commenced only within recent years.

Record teak log.

As far as we are aware, the Ruby Mines Division, Upper Burma, can claim the honour of having produced the largest teak log yet recorded. This log, which was launched into a feeder of the Shweli river by Messrs. Darwood & Co., about 1898, measured 82½ feet in length, over 12 feet in girth at the base and over 7 feet in girth at the top, and contained 507 cubic feet of timber.

APPENDIX I.

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
Northern.	Katha	. Mohnyin	21,024	32·9	2,336	23,360	36·5	1895-96 to 1909-10	*Situation* :—In Katha District, about lat. 24°45′ N., in the Upper Irrawaddy valley, to the west of that river. *Configuration* flat, a portion being a raised plateau about 150 to 200 feet above the level of the remainder. *Rock and soil* : argillaceous sandstone; soil a heavy clay to a light loam. *Rainfall* probably about 90″. *Temperature* 40°-100°. *Forest:* (1) Evergreen without teak, about $\frac{1}{10}$ of the area, (2) Teak-bearing moist forest with bamboos, chiefly *Cephalostachyum pergracile*, $\frac{1}{10}$ of the area, (3) Teak-bearing forest with few or no bamboos, about $\frac{2}{5}$ of the area, teak being found in groups of varying size, usually in almost pure masses with little or no undergrowth, the trees attaining large dimensions, (4) Dry forest, teak being associated with *Shorea obtusa*, *Pent-*	Mr. E. A. O'Bryen.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working Plan.	Brief description of forest.	Author of Working-Plan.
									acme suavis, etc., and being usually stunted and not plentiful; this type occupies about ⅗ of the area. *Fire-protection* started immediately before the working-plan.	
Northern	Myittha .	Kale Working Circle.	115,160·4	179·9	27,462·6	142,623	222·8	1906-07 to 1957-58	*Situation*:—The western drainage of the Chindwin River in the Kale sub-division of the Upper Chindwin District, about 23½° N. Lat. *Configuration* hilly, highest point 2,778 feet. Ranges of serrate form, with steep escarpments to the west. *Rock and soil*, sandstone, with occasional congomerate and thin beds of clay. Soil sandy loam with varying proportions of sand. *Rainfall* probably over 70″. *Teak forest* chiefly dry mixed, with *Dendrocalamus strictus*, the chief bamboo; *Bambusa polymorpha* is abundant only in one locality, in which teak is also	Mr. R. E. Marsden.

									found in greatest abundance. *Fire-protection* started 7 years previous to the working-plan and continued over part of the area annually.	
Do.	Ditto	Taungdwin	90,647 [only 70,600 suitable for girdling].	141·6	86,148	176,795 [including village exclusions].	276·2	1908-09 to 1937-38	*Situation* :—Chindwin western drainage, between 22°45′ and 22°15′ N. Lat. *Configuration*, except for a few alluvial flats, very steep and hilly; highest point 4,451 ft. *Rock* soft sandstone with occasional shale and conglomerate. *Temperature* 45°-106°. *Rainfall* about 55″. *Teak forest* of a rather dry type, the prevailing bamboo being *Dendrocalamus strictus*, but there are large tracts where *Cephatostachyum pergracile* and *Bambusa Tulda* predominate. *Dendrocalamus Brandisii* is common along streams and *Thyrsostachys Oliveri* on ridges. The chief associates are pyinkado (*Xylia dolabriformis*), *Terminalia tomentosa*, padauk (*Pterocarpus macrocarpus*) and *Homalium tomentosum*. *Fire-protection* commenced about 10 years prior to the working-plan, but was abandoned some years later, never having been successful.	Mr. J. C. Hopwood.
Do.	Upper Chindwin.	Mawku Working Circle.	185,899	290·5	11,812	197,711	308·9	1907-08 to 1930-31	*Situation* :—Upper Chindwin, west of the Chindwin River between 23°33′ and 24°1′ N. lat. *Configuration* hilly, except for a few square miles of nearly flat land; highest point 3,220 ft. *Rock and soil*, chiefly sandstone, associated with conglomerates, shales, clays and coal seams. *Temperature* below 45° to about 100°. *Rainfall* aver-	Mr. L. C. Davis.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
									age probably between 70″ and 80″. *Teak forest* chiefly dry mixed, associated with *Xylia dolabriformis* and *Terminalia tomentosa*: chief bamboos *Cephalostachyum pergracile*, *Dendrocalamus strictus* and *Dendrocalamus Brandisii*, with other species less plentifully distributed. *Fire-protection* was commenced about 15 years previous to the working-plan and was continued over part of the area annually with varying success.	
Southern	Ruby Mines	Nanhan, Nampaw and Subôk.	92,396·2	144·4	66,542	158,938·2	248·3	1905 to 1935	*Situation* in Momeik State, on the right bank drainage of the Shweli River, about Lat. 23°30′ N. *Configuration* from flat or gently rising ground to hilly country; highest point 2,721 feet. *Rock and soil* gneiss with occasional limestone; in the west sandstone and shale, with occasional laterite, on low-lying and gently graded	Mr. H. L. P. Walsh.

									localities. Soil from gneiss and limestone a deep rich clay or clay loam ; soil from sandstone and laterite sandy loam of somewhat poor teak producing capacity. *Teak forest* most mixed with *Dendrocalamus Hamiltonii* on the lower ground, and on the slopes *Cephalostachyum pergracile* and *Dendrocalamus membranaceus*, with *Thyrsostachys Oliveri* on the drier ridges and spurs. *Fire-protection* not yet attempted.	
Do. .	Do. .	Maingtha, Kunchaung and Namne.	224,063·3	350	17,290·9	241,354·2	377	1906 to 1926	*Situation* in Momeik State, on the right bank drainage area of the Shweli River. *Configuration* from gently graded to hilly and steep ; h ghest point 2,575 feet. *Rock and soil* gneiss and limestone producing a rich clay or clay loam over part of the area and sandstone and shale, with a little laterite over the remainder, the soil varying from a rich fertile loam to a poorer sandy soil. *Teak forest* chiefly very moist mixed, with dense bamboo and evergreen undergrowth, the chief bamboos being *Cephalostachyum pergracile*, *Dendrocalamus Hamiltonii* and *D. membranaceus ;* dry mixed forest comprises part of the stock, the chief bamboos being *Thyrsostachys Oliveri*, *Bambusa Tulda* and poorly grown *Cephalostachyum pergracile*. *Fire-protection* extended over part of the area for about 10 years previous to the working-plan.	Ditto.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
Southern	Ruby Mines	Hintha Working Circle (Hintha, Ondok and Kyauktaung Reserves).	80,115·8	125·2	46,509·2	126,625	197·9	1908 to 1938	*Situation* between the Shweli and Irrawaddy rivers in the Ruby Mines District and extending into Momeik State. *Configuration* chiefly undulating, never very steep, with some almost level stretches: highest point 1,727 feet. *Rock and soil:* partly limestone, partly sandstone, partly slates and shales, and partly gravels and clays associated with laterite. *Rainfall* probably about 50". *Teak forest* of three types: (1) Dry mixed (semi-*indaing*), the chief bamboos being stunted *Dendrocalamus strictus* and *Bambusa Tulda*; teak of poor growth, (2) upper mixed with bamboos *Thyrsostachys Oliveri*, *Cephalostachyum pergracile* and others, chiefly on limestone and richer sandstone; teak is here of better quality than elsewhere, (3) moist mixed where teak is associated chiefly with *kanyin* (*Dip-*	Mr. G. R. Jeffery.

									terocarpus alatus) and does not usually grow in a healthy manner, though it occasionally shows very fine growth; bamboos *Dendrocalamus Hamiltonii*, *Cephalostachyum pergracile*, *Oxytenanthera albociliata* forming dense masses, and others, also various canes. *Fire-protection* has never been attempted.	
Do.	**Pyinmana**	**Yeni**	**37,524·6**	59	12,838·4	50,363	78·7	1897 to 1927	*Situation:* Pegu Yoma E. slopes. *Configuration*, except for a few flat areas, the country is hilly; highest point 961 feet. *Rock and soil* sandstone and shale with occasional conglomerate, and laterite in parts; soil a rich loam to a loamy sand. *Rainfall* probably about 70″. *Temperature* about 50°-102°. *Teak forest.* About 50 sq. miles are dry upper mixed, with bamboos *Oxytenanthera albociliata*, *Cephalostachyum pergracile* and others; moist mixed with *Bambusa polymorpha* and *Cephalostachyum pergracile*, occupies 9 sq. miles. *Fire-protection* commenced a year previous to the working-plan.	**Mr. S. Carr.**
Do.	Do.	**Minbyin**	**117,183·3**	183	14,781·4	131,964·7	206	1899 to 1929	*Particulars* as in Yeni, which the Minbyin Reserve adjoins. *Teak forest* both dry and moist upper mixed, with bamboos as in Yeni. *Fire-protection* not yet started at time of working-plan.	Ditto.
Do.	Do.	**Yonbin**	**73,252·1**	114	8,042·9	81,295	127	1900 to 1930	*Particulars* as in Yeni and Minbyin, but forest slightly drier.	**Mr. R. S. Troup.**

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forest in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
Southern	Pyinmana .	Sinthe . .	66,483·3	104	1,479·9	67,963·2	106·2	1902 to 1934	*Situation:* Pegu Yoma E. slopes, near the northern extremity of the range, and bordering on the dry zone of Upper Burma. *Configuration* hilly; highest elevation 1,500 feet. *Rock and soil:* sandstone and shale, with soil a very sandy to a clayey loam. *Rainfall* slightly over 40″. *Temperature* about 47°-109°. *Teak forest* very dry, and poor as compared with the other Pyinmana Reserves: prevailing bamboo *Dendrocalamus strictus*. *Fire-protection* not started at time of working-plan.	Mr. F. Linnell.
Do. .	Do. . .	Ngalaik . .	77,583	121	3,001	80,584	126	1902 to 1932	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly, up to 1,000 feet elevation. *Rock and soil:* sandstone and shale, with soil chiefly a clayey loam, and varying from clay to almost pure sand. *Rainfall* between 50″ and 60″. *Temperature* 50°-105°. *Teak forest* upper	Mr. G. E. S. Cubitt.

									mixed, dry rather than moist, with chief bamboos *B. polymorpha*, *Cephalostachyum pergracile* and *Oxytenanthera albociliata*, with *Dendrocalamus strictus* and *Bambusa Tulda* on dry localities. *Fire-protection* not started at time of working-plan.	
Do.	Do.	Yanaungmyin, Kaing and Palwe.	119,255·5	186	4,506·5	123,762	193·3	1903 to 1933	*Situation*, *Configuration*, *Rock*, *Soil* and *Climate*, as in Ngalaik. *Teak forest* chiefly moist upper mixed, with dry mixed on ridges and upper slopes; bamboos as in Yeni, Minbyin and Ngalaik. *Fire-protection* started 10 years previous to the working-plan and extended over part of the area.	Mr. C. W. Doveton.
Do.	Do.	Taungnyo	64,729	101	3,268	67,997	106	1903 to 1933	*Particulars* as in Ngalaik.	Ditto.
Do.	Do.	Pozaungdaung	44,022	69	7,989	52,011	81	1903 to 1943	*Particulars* as in Ngalaik. The hills reach a maximum height of 2,055 feet above M. S. L.	Mr. G. E. S. Cubitt.
Do.	Do.	Ziyaing-Mehaw	12,262·5	19	12,441·8	24,704·3	38	1903 to 1923	*Situation* east bank of the Sittang River. *Configuration*: except for a small flat portion, the whole area is very hilly, the hills rising to 4,000 feet. *Rock and soil*: partly laterite and partly gneiss and porphyritic granite; soil very sandy loam to pure sand. Teak is absent as a rule on the laterite. *Rainfall* probably about 60″. *Temperature* probably about 50° to 105°. *Teak forest* moist upper mixed, with *Dendrocalamus strictus*, *Bambusa polymorpha* and *Cephalostachyum pergracile*, the chief bamboos. *Fire-protection* not started at time of working plan.	Mr. F. H. Todd.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. TEAK-BEARING. Acres.	AREA. TEAK-BEARING. Equivalent in sq. miles.	AREA. NON-TEAK-BEARING. Acres.	AREA. TOTAL. Acres.	AREA. TOTAL. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
Southern	Mandalay .	Madaya Range Forests (a rough working-plan in which no enumerations were carried out).	..	97*	..	..	388·5	1907 to 1927	*Situation*: Chiefly in the drainage of the Madaya river north of Mandalay, but partly to the west of the Madaya Irrawaddy watershed. *Configuration* hilly and often precipitous, the hills rising to 3,500 feet. *Rock*: Chiefly gneiss with outcrops of limestone. *Rainfall* probably between 60" and 75". *Teak forest* fairly moist mixed: chief bamboos *Thyrsostachys Oliveri* in the moister parts and *Dendrocalamus strictus* in the drier parts. *Fire-protection* started 5 years previous to the working-plan over a small portion of the area.	Mr. H. H. Forteath.
Do.	Minbu .	Taungdwingyi Reserves (a rough working-plan; enumerations were carried out over about	187,036	292·2	68,203	255,239	398·8	1907 to 1927	*Situation*: Pegu Yoma western slopes in Magwe Civil District. *Configuration* hilly; highest point 2,032 feet. *Rock and soil* sandstones and shales; laterite common, conglomerate rare.	Mr. F. A. Leete.

		2,100 acres in 1898).						Soil sandy loam, poor on ridges, good elsewhere. *Rainfall* about 37″. *Teak forest* dry mixed : chief bamboo *Dendrocalamus strictus.* Teak much overworked in the past. *Fire-protection* started systematically about 5 years previous to the working-plan over part of the area.	
Pegu .	Thayetmyo .	East Yoma, Satuwa and Tindaw.	84,022·2	131·3	1,323·6	85,345·8	133·3	1906-07 to 1937-38	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly to precipitous; highest point 2,003 feet. *Rock and soil:* Sandstone and shale ; soil sandy loam, with poor shabby gravel on ridges. *Rainfall* about 45″. *Temperature* 44° to 109°. *Teak forest* of upper mixed type, prevailing bamboos being *Dendrocalamus strictus* on ridges and *Bambusa polymorpha* elsewhere. *Fire-protection* only recently started to any extent.	Mr. A. Rodger.
Do. .	Prome .	Shwele .	73,489	114·8	..	73,489	114·8	1892-93 to 1921-22	*Situation :* Pegu Yoma W. slopes. *Configuration :* Undulating and slightly hilly to precipitous, highest point 1,539 feet. *Rock and soil :* Sandstone and shale ; soil sandy loam or pure sand to clayey loam or pure clay. *Rainfall* at Prome 50″, but in the forests probably considerably more. Temperature about 50° to 107°. *Teak forest* of upper mixed type, $\frac{2}{3}$ dry forest with *Dendrocalamus strictus* and $\frac{1}{3}$ moist with *Bambusa polymorpha*, the chief bamboo. *Fire-protection* started about 15 years previously and continued gradually.	Mr. H. Carter.

*A very rough approximation.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA.					Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
			TEAK-BEARING.		NON-TEAK-BEARING.	TOTAL.				
			Acres.	Equivalent in sq. miles.	Acres.	Acres.	Equivalent in sq. miles.			
Pegu .	Prome .	Nawin . .	134,591·8	210·3	..	134,591·8	210·3	1893-94 to 1922-23	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly, highest point 1,885 feet. *Rock and soil:* Sandstone and shale, soil sandy loam to clay and clayey loam. *Climate:* Similar to Shwele. *Teak forest* of upper mixed type, $\frac{5}{12}$ dry and $\frac{7}{12}$ moist as in Shwele. *Fire-protection* started 20 years previously over a small area and continued subsequently.	Mr. J. Messer.
Do. .	Zigôn .	Kangyi . .	4,896	7·6	..	4,896	7·6	1898-99 to 1921-22	*Situation:* Plains of Hlaing or Myitmaka River valley. *Configuration* flat. *Rock and soil* alluvium with light grey loam to stiff loam, sometimes with imperfect drainage. *Rainfall* about 100″. *Temperature* 60° to 105°. *Teak forest* of lower mixed type with no bamboos over most of the area and *Bambusa Tulda* plentiful in one strip. Teak attains to large size. *Fire-protection* commenced 15 years prior to the working-plan.	Mr. G. Q. Corbett.

Do.	Do.	Gamon	44,579	69·6	17,860	62,439	97·5	1889-90 to 1923-24	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly, highest point about 2,000 feet. *Rock and soil,* sandstone and shale; soil a loam with varying proportions of sand and clay, rich in valleys and on lower slopes and poor and shallow on ridges. *Rainfall* about 100." *Temperature* 55° to 105°. *Teak forest* of upper mixed type, $\frac{3}{4}$ dry with *Dendrocalamus strictus* in driest parts and *Bambusa Tulda* on the more fertile parts, and $\frac{1}{4}$ moist with *Bambusa polymorpha* and *Cephalostachyum pergracile* the chief bamboos. *Fire-protection:* nothing but plantations protected at time of compiling working-plan.	Mr. H. Hoghton.
Do.	Do.	Bawbin	71,747	112·1	10,930	82,677	129·2	1890-91 to 1919-20	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly, highest point 2,760 feet. *Rock and soil* similar to Gamon. *Climate* similar to Gamon. *Teak forest* similar to Gamon, $\frac{2}{3}$ dry and $\frac{1}{3}$ moist. *Fire-protection* as in Gamon.	Ditto.
Do.	Do.	Taungnyo	107,169	167·4	..	107,169	167·4	1891-92 to 1920-21	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly, highest point 2,150 feet. *Rock and soil* similar to Gamon. *Rainfall* about 90" *Temperature* 58° to 107°. *Teak forest* similar to Gamon, $\frac{1}{3}$ dry, $\frac{2}{3}$ moist. *Fire-protection* previously confined to plantations and small adjoining area.	Mr. G. Q. Corbett.
Do.	Tharrawaddy	Thonzè	53,534	83·6	16,200	69,734	108·9	1885-86 to 1913-14	*Situation:* Pegu Yoma W. slopes. *Configuration* hilly, highest point 2,261 feet. *Rock and soil* and *climate* similar to Gamon. *Forest* upper mixed type both	Mr. J. W. Oliver.

E

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
									moist and dry, of same types as in Gamon. *Fire-protection* previously confined mainly to plantations, and started 9 years previous to the working-plan.	
Pegu	Tharrawady	Kadinbilin	39,807	62·2	11,385	51,192	79·9	1885-86 to 1915-16	*Situation*: Pegu Yoma W. slopes. *Configuration* hilly: highest points 2,261 feet (Thonzè), 1,777 (Kadinbilin). *Rock and soil* and *climate* similar to Gamon. *Teak forest* of upper mixed type, resembling that of Gamon. Môkka has 3/8 dry and 5/8 moist, Minhla 2/3 dry and 1/3 moist. *Fire-protection* started in a portion of Kadinbilin and Môkka 13 years previously and in a portion of Minhla 6 years previously, and in a portion of Minhla 6 years previously, plantations were separately protected previous to the working-plans in all the Working Circles.	Mr. T. H. Aplin.
Do.	Do.	Kônbilin	12,460	19·5	3,528	15,988	24·9	Do.		
Do.	Do.	Môkka	24,668	38·5	..	24,668	38·5	Do.		
Do.	Do.	Minhla	25,883	40·4	..	25,883	40·4	1889-90 to 1923-24		Mr. H. A. Hoghton.

Do.	Do.	Satpôk	5,335	8·3	21	5,356	8·4	1904-05 to 1928-29	*Situation:* Plains of the Hlaing (My maka) River valley. *Configuration* flat. *Rock and soil* alluvial deposits: soil rich loam with occasional pans of clay. *Rainfall* 80″. *Temperature* 55° to 105°. *Teak forest* of lower mixed type, the chief associates of teak being *Terminalia tomentosa* in Satpôk and *Dillemia pentagyna* in Sitkwin and Thindawyo. Bamboos almost entirely absent except in Satpôk, where *Bambusa Tulda* is common near streams. Forests not fire-protected.	Mr. R. S. Troup.
		Sitkwin	1,325	2·01	58	1,383	2·1	Do.		
		Thindawyo	6,551	10·2	..	6,551	10·2	Do.		
Do.	Rangoon	Plains forests	51,156	79·9	1,858*	53,014	82·8	1905 to 1924	*Situation:* Plains of the Hlaing River valley. *Configuration* chiefly flat with occasional slight undulations. *Rock and soil* chiefly laterite, with occasional outcrops of sandstone and shale; soil very variable. *Rainfall* about 100″. *Teak forest* only in patches. Main type lower mixed, with *Indaing* forest interspersed; quality varies much.	Mr. J. J. Rorie.
Do.	Do.	Hill forests	120,570·1	188·4	..	120,570·1	188·4	1905 to 1935	*Situation:* Pegu Yoma W. slopes near the southern extremity of the Range. *Configuration* hilly; highest point 1,561 feet. *Rock and soil:* Sandstone and shale, with some laterite. Soil sandy to clayey loam or stiff clay. *Rainfall* about 100″. *Temperature* 55° to 105°. *Teak forest* of upper mixed type, partly moist, with *Bambusa polymorpha* and *Cephalostachyum pergracile*, and partly dry with	Ditto.

*Area of teak plantations excluded from the present calculations.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA.					Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
			TEAK-BEARING.		NON-TEAK-BEARING.	TOTAL.				
			Acres.	Equivalent in sq. miles.	Acres.	Acres.	Equivalent in sq. miles.			
									Dendrocalamus strictus and *Bambusa Tulda* as the chief bamboos. *Fire-protection* commenced over part of the area 4 years previous to the working-plan.	
Pegu .	Pegu . .	South Zamayi .	145,686	227·6	585	146,271	228·5	1905 to 1935	*Situation:* S.E. extremity of Pegu Yoma range, on left drainage of Pegu river. *Configuration* chiefly hilly, highest point 947 feet. *Rock and soil* sandstone and shale, with occasional conglomerate. Soil sandy or clayey loam. *Rainfall* about 125″. *Temperature* 50° to over 100°. *Teak forest* of moist upper mixed type, with *Xylia dolabriformis*, as chief auxiliary species and *Bambusa polymorpha* and *Cephalostachyum pergracile*, the principal bamboos. Nearly the whole reserve fire-protected for 4 years previous to working-plan.	Mr. J. J. Rorle.

Tenasserim.	Toungoo .	Kabaung .	188,934·2	295·2	..	188,934·2	295·2	1894-95 to 1923-24	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly; highest point 1,849 feet. *Rock and soil:* Sandstone and shale; soil clay or clayey loam to sandy loam. *Rainfall* 76″ or probably more. *Temperature* 49°-108° (at Toungoo). *Teak forest* upper moist mixed, the prevailing bamboos being *Bambusa polymorpha* and *Cephalostachyum pergracile*. *Fire-protection* confined to small area of plantations.	Mr. H. Carter.
Do. .	Do. .	Bondaung .	23,757·1	37·1	..	23,757·1	37·1	1894-95 to 1923-24	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly; highest point 1,325 feet. *Rock and soil* and *climate* as in Kabaung. *Teak forest* moist mixed, with prevailing bamboos *B. polymorpha* (the commonest), *Cephalostachyum pergracile* and *Oxytenanthera albociliata*. Evergreen tropical forest near streams. *Fire-protection* introduced on a large scale 8 years previously.	Ditto.
Do. .	Do. .	West Swa, Sabyin and Lonyan.	94,694	148	..	94,694	148	1897-98 to 1928-29	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly; highest point 1,655 feet. *Rock, Soil, Climate,* and *Teak forest* as in Kabaung. *Fire-protection* not started at time of working-plan.	Mr. F. J. Branthwaite.
Do.	Do. .	Gwethe . .	30,871·4	48·2	..	30,871·4	48·2	1899-1900 to 1923-24	*Situation:* W. slopes of Karen Hills, east of Sittang River. *Configuration* flat to hilly, the hills often having flat tops: teak occurs chiefly on the hilly portions, the flat ground and flat tops of hills being covered with *indaing*. *Rock and soil* metamorphic rock of grani-	Ditto.

APPENDIX I—*contd.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried out—contd.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
									toid or schistose character, decomposing into a coarse sandy loam, laterite on the flat hill-tops. *Climate* as in Kabaung. *Teak forest* moist upper mixed, the chief bamboos being *B. polymorpha* and *Cephalostachyum pergracile*. *Fire-protection* not started at time of working-plan.	
Tenasserim	Toungoo .	Saing Wg. Circle	108,384	169·3	.. [Non-teak-bearing forest occurs in the shape of *indaing* and *evergreen*, but the area has not been estimated separately; teak-bearing forest occupies a much greater area than the other types.]	108,384	169·3	1899-1900 to 1928-29	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly; highest point 896 feet. *Rock and soil* and *climate* as in Kabaung. *Teak forest* moist mixed, with *B. polymorpha*, the chief bamboo, and *Cephalostachyum pergracile* and *Gigantochloa albociliata* also common. *Fire-protection* started over part of the area 22 years previously.	Mr. F. J. Branthwaite.
Do. .	Do. .	Kyaukmasin .	25,360·8	39·6	71	25,431·8	39·7	1898-99 to 1925-26	*Situation:* Pegu Yoma E. slopes. *Configuration* hilly; highest point 1,824 feet.	Mr. A. M. Burn-Murdoch.

									Rock and soil and *climate* as in Kabaung. *Teak forest* as n Kabaung, but slightly drier. *Fire-protection* not started at time of working-plan.	
Do.	Do. .	Pyu-Chaung and Pyu-Kun.	287,647·2	449·4	..	287,647·2	449·4	1902-03 to 1934-35	*Situation :* Pegu Yoma. E. slopes. *Configuration* hilly ; highest point 1,781 feet. *Rock and soil, Cimate,* and *Teak forest* as in Kabaung. *Fire-protection* not started at time of working-plan.	Mr. H. W. A. Watson.
Do. .	Shwegyin .	Tonkan . .	14,041	21	5,620	19,661	31	1906-07 to 1913-14	*Situation :* Plain of the Sittang valley, between that river and the Pegu Yoma. *Configuration* flat, with low hills only on the west, where evergreen forest occurs. *Rock and soil :* Sandstone, covered with alluvium of sandy loam or pure sand. *Rainfall* about 110″. *Temperature* about 50° to 108°. *Forest* lower mixed, with large areas of "kaing" grass : teak of good quality occurs only in patches, here and there, teak trees of poor growth being found scattered elsewhere: there is a considerable amount of evergreen. *Fire-protection* not hitherto successful.	Mr. J. J. Rorie.
Do. .	Do. .	Nyaunglebin Wg. Circle.	363,618·4	568·2	888	364,506·4	569·5	1906-07 to 1935-36	*Situation :* Pegu Yoma E. slopes. *Configuration* hilly, with a little flat land ; highest point 1,661 feet. *Rock and soil :* Sandstone and shale ; soil a loam with varying proportions of sand, often stony and shaley on ridges · clay or stiff loam in valleys. *Rainfall* about	Mr. H. W. A. Watson.

APPENDIX I—*concld.*

Area statement and brief description of Burma teak forests in which working-plans operations have been carried cut—concld.

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AREA. Teak-bearing. Acres.	AREA. Teak-bearing. Equivalent in sq. miles.	AREA. Non-teak-bearing. Acres.	AREA. Total. Acres.	AREA. Total. Equivalent in sq. miles.	Period of Working-Plan.	Brief description of forest.	Author of Working-Plan.
									110". *Temperature* about 50° to 108°. *Teak forest* chiefly moist upper mixed, with the chief bamboos. *B. polymorpha* and *Cephalostachyum pergracile*. Lower mixed forest, in which teak is scarce, occurs on flat land. *Fire-protection* commenced over a small area a few years previous to the working plan: the great bulk of the area is unprotected.	
Do. .	Thaungyin .	Lower Thaungyin Working Circle.	93,229	145·7	76,451	169,680	265·1	1908-09 to 1937-38	*Situation:* Left bank of the Thaungyin River, Tenasserim. *Configuration* hilly except for alluvial flats along the Thaungyin river; highest point 2,919 feet. *Rock and soil:* Argillaceous sandstone and shale, frequently calcareous, resting on igneous or metamorphic rocks also crystalline limestone forming rocky peaks and crags, and laterite in many parts of the Thaungyin valley; soil sandy loam	Mr. A. E. Ross.

to stiff clay. *Rainfall* over 100". *Temperature* about 40° to 100°. *Teak forest* semi-moist and dry mixed, the chief bamboo being *Oxytenanthera albociliata* with *Dendrocalamus strictus* on higher slopes and ridges. *Fire-protection* extended over part of the area for some years before the working-plan.

APPEN

Statistics of Growing Stock in

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AVERAGE TEAK GROWING STOCK AND DEAD TREES PER 100 ACRES OF TEAK-BEARING FOREST.								
			Sound trees.					Unsound.		Dead trees.	Total sound trees 3′ and over in girth per 100 acres.
			I 7′ and over.	II 6′-7′.	III 4½′-6′.	IV 3′-4½′.	V Under 3′.	Above 3′.	Below 3′.		
Northern .	Katha . .	Mohnyin .	241		190	276	248	380	371	11	707
	Myittha . .	Kale Working Circle . .	50	43	76	64	59*	25	..	28	233
	Ditto . .	Taungdwin† .	..	..	..	..	..	..	..	..	..
	Upper Chindwin	Mawku Working Circle . .	67	40	55	57	495	83	..	38	219
Southern .	Ruby Mines .	Nanhan, Nampaw and Subôk	27	21	69	140	205	110	52	20	257
	Ditto .	Maingtha, Kunchaung and Nanme . .	29	11	40	121	237	88	63	13	201
	Ditto .	Hintha Working Circle . .	17	8	31	..	..	..	..	..	..
	Pyinmana .	Yeni . .	59	45	92	120	768	28	15	6	316
	Ditto .	Minbyin . .	37	23	61	100	776	44	53	2	221
	Ditto .	Yônbin . .	46	27	56	94	792	32	36	2	223
	Ditto .	Sinthe . .	9	15	50	90	1,964	29	50	19	164
	Ditto .	Ngalaik . .	42	33	97	185	1,412	26	40	7	357
	Ditto .	Yanaungmyin, Kaing and Palwe . .	30	18	56	109	835	37	31	6	213
	Ditto .	Taungnyo .	11	13	47	108	1,008	23	24	5	179
	Ditto .	Pozaungdaung	30	21	48	91	1,151	26	27	3	190
	Ditto .	Ziyaing-Mehaw	104	57	97	97	131	45	9	7	355
	Minbu . .	Taungdwingyi .	15		40	100	..	..	..	..	155
Pegu .	Thayetmyo .	East Yoma, Satsuwa and Tindaw . .	37	22	51	121	180	22	13	12	231
	Prome . .	Shwele . .	28	27	44	120	446	10	11	12	219
	Ditto . .	Nawin . .	52	31	57	118	665	18	14	18	258
	Zigôn . .	Kangyi . .	62	50	126	205	2,920	18		5	441
	Ditto . .	Gamôn§ . .	78	34	87	163	309	14	13	8	362

* Nothing under 1½ ft. in girth
† The growing stock was not
‡ The total growing stock of
§ In these working-plans the
above.

DIX II.

Burma Teak Forests.

PERCENTAGE OF EACH AGE CLASS (SOUND TEAK ONLY). I 7′ and over.	II 6′-7′.	III 4½′-6′.	IV 3′-4½′.	V Under 3′.	Percentage of teak trees 3′ in girth and over in total growing stock of all species of same dimensions.	Nature of Valuation Surveys.
25		20	29	26	Other species were not enumerated.	Linear surveys over 5·9% of the total area.
17	15	26	22	20*	11	Sample plots over 27·5% of the productive area.
16		26	33	25	All other species were not enumerated.	Linear surveys over 4·2% of area suitable for girdling.
9	6	8	8	69		Sample plots over 24% of the teak-bearing area.
6	5	15	30	44	12	Sample plots over 25·3% of the productive area.
7	2	9	28	54	‡	Sample plots over 26·7% of the productive area.
..	..	..	..	..	‡	Linear surveys over 14·7% of the productive area.
6	4	8	11	71	12	Sample plots over 24·8% of the productive area.
4	2	6	10	78	10	Sample plots over 26% of the productive area.
5	3	5	9	78	12	Sample plots over 27·8% of the productive area.
1	1	3	4	91	7	Sample plots over 26% of the productive area.
2	2	6	10	80	20	Sample plots over 31% of the productive area.
3	2	5	10	80	14	Sample plots over 23·9% of the productive area.
1	1	4	9	85	12	Sample plots over 31% of the productive area.
2	1	4	7	86	7	Sample plots over 32·7 % of the productive area.
21	12	20	20	27	‡	Sample plots over 34% of the productive area.
..	..	..	..	..	..	The figures are based on linear enumerations made in 1898 over about 2,100 acres, or slightly over 1% of the teak-bearing area; the figures, therefore, can be only very roughly approximate.
9	5	13	29	44	15	Sample plots over 29% of the total area.
4	4	7	18	67	13	Sample plots over 30% of the total area.
6	3	6	13	72	16	Sample plots over 23·9% of the total area.
2	1	4	6	87	29	The whole area was enumerated.
12	5	13	24	46	19	Sample plots over 12·5% of the total area.

was enumerated.
calculated in detail.
other species was not enumerated.
trees are arranged in diameter classes, and the figures have here been corrected to correspond to the girth classes shown

APPEN

Statistics of Growing Stock in

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	AVERAGE TEAK GROWING STOCK AND DEAD TREES PER 100 ACRES OF TEAK-BEARING FOREST.								
			SOUND TREES.					UNSOUND.		Dead trees.	Total sound trees 3′ and over in girth per 100 acres.
			I 7′ and over.	II 6′-7′.	III 4½′-6′.	IV 3′-4½′.	V Under 3′.	Above 3′.	Below 3′.		
Pegu	Zigôn	Bawbin§	101	31	81	170	656	7	14	7	383
	Ditto	Taungnyo§	74	27	67	148	413	4	10	6	316
	Tharrawaddy	Thônze§	62	19	67	162	499	11	20	5	310
	Ditto	Kadinbilin§	87	30	91	200	543	17	22	5	408
	Ditto	Kônbilin§	88	24	69	195	724	14	10	12	376
	Ditto	Mokka§	57	12	63	140	502	9	35	2	272
	Ditto	Minhla§	86	35	78	139	380	22	9	3	338
	Ditto	Satpôk	56	66	130	203	344	31	..	4	455
		Sitkwin	49	35	86	105	113	30	..	3	275
		Thindawyo	11	11	17	29	46	11	..	1	68
	Rangoon	Plains	7		10	14	80	..	..	..	31
	Ditto	Hills	27	30	54	90	226	18	8	6	201
	Pegu	South Zamayi	24	26	59	65	49	21	7	4	174
Tenasserim	Toungoo	Kabaung	36	20	34	60	395	19	15	7	150
	Ditto	Bondaung	108	63	91	147	799	30	25	7	409
	Ditto	West Swa, Sabyin and Lonyan	30	15	29	46	246	27	16	9	120
	Ditto	Gwethe	49	24	40	42	256	48	21	8	155
	Ditto	Saing Working Circle	41	15	26	39	418	34	23	9	121
	Ditto	Kyaukmasin	37	31	76	104	452	61	49	26	248
	Ditto	Pyu-Chaung and Pyu-Kun	30	28	62	79	482	30	39	10	199
	Shwegyin	Nyaunglebin Working Circle	24	22	50	60	52	30	11	6	156
	Ditto	Tonkan	5	6	16	40	..	..	..	..	67
	Thaungyin	Lower Thaungyin Working Circle	26	20	51	115	241‖	32	100	11	212

§ In these working-plans the trees are arranged in diameter classes, and the

‖ Dominant saplings only.

DIX II—*contd.*

Burma Teak Forests—contd.

PERCENTAGE OF EACH AGE CLASS (SOUND TEAK ONLY).					Percentage of teak trees 3′ in girth and over in total growing stock of all species of same dimensions.	Nature of Valuation Surveys.
I 7′ and over.	II 6′-7′.	III 4½′-6′.	IV 3′-4½′.	V Under 3′.		
10	3	8	16	63	33	Sample plots over 18·8% of the total area.
10	4	9	20	57	19	Sample plots over 24% of the total area.
8	2	8	20	62	17	Sample plots over 11·8% of the whole teak forest.
9	3	10	21	57	19	Sample plots over 18% of the total area.
8	2	6	18	66	17	Sample plots over 22% of the productive area.
7	2	8	18	65	13	Partly sample plots over 27% of the total area and partly linear surveys over less than 3% of the total area.
12	5	11	19	53	13	Sample plots over 20% of the total area.
7	9	16	25	43	16	The whole area was enumerated.
13	9	22	27	29	10	
10	10	15	25	40	5	
6		9	13	72	1	Sample plots over 41% of the total area.
6	7	13	21	53	13	Sample plots over 26·4% of the total area.
11	12	26	29	22	9	Sample plots over 24·6% of the total area.
7	4	6	11	72	11	Sample plots over 23% of the total area.
9	5	8	12	66	21	Sample plots over 25% of the total area.
8	4	8	12	68	8	Sample plots over 24% of the total area.
12	6	10	10	62	6	Sample plots over 34% of the total area.
8	3	5	7	77	6	Sample plots over 25·5% of the total area.
5	4	11	15	65	13	Sample plots over 26·2% of the total area.
4	4	9	12	71	11	Sample plots over 27% of the total area.
12	10	24	29	25	8	Sample plots over 25% of the total area.
7	9	24	60	..	2	Sample plots over 10% of the forest area.
..	..	..	..	..	Other species were not enumerated.	Sample plots over 38% of the productive area or 20% of the total area.

figures have here been corrected to correspond to the girth classes shown above.

APPEN

Statement showing rate of growth of teak in natural forest,

Forest Circle.	Forest Division.	Name of Forest.	Average age of tree of girth of 3′	4½′	6′	7′
Northern	Katha	Mohnyin	60	90	133	166
	Myittha	Kale Wg. Circle	60	92	129	156
	Ditto	Taungdwin	51	81	120	150
	Upper Chindwin	Mawku Wg. Circle	52	84	129	165
Southern	Ruby Mines	Nanhan Nampaw and Subôk.	53	91	138	176
	Ditto	Maingtha, Kunchaung and Nanme.	52	83	123	155
	Ditto	Hintha, Ondôk and Kyauktaung.	64	108	152	189
	Pyinmana	Yeni	50	77	113	136
	Ditto	Minbyin	78	116	161	186
			59	86	124	149
			63	92	131	156
	Ditto	Yônbin	57	100	130	150
	Ditto	Sinthe	66	105	148	176
	Ditto	Ngalaik	55	85	121	151
	Ditto	Yanaungmyin, Kaing and Palwe.	47	86	120	136
	Ditto	Taungnyo	57	85	116	140
	Ditto	Pozaungdaung	69	110	165	..
			62	88	123	154
			64	98	141	173
	Ditto	Ziyaing-Mehaw	62	112	153	190
	Mandalay	Madaya	..	..	145	..
Pegu	Thayetmyo	East Yôma, Satsuwa and Tindaw.	50	83	120	146

DIX III.

exploitable age and size and other particulars.

Exploitable age adopted or rotation (years).	Exploitable size (ordinary minimum girdling limit or girth).	PERIOD AND SUB-PERIODS OF WORKING UNDER THE WORKING-PLAN. Period.	Sub-periods.	REMARKS.
		Years.		
160	7 feet	15	3 of 5 years each.	
180	7 feet	1st of 20 years and 2nd of 52 years.	5 of 4 years each and 4 of 8 years each.	Allowance for bark not made dur ng ring count ngs, but 7 or 8 years was allowed for thickness of bark in fixing the exploitable age (180 years).
180	7½ feet	30	5 of 6 years each.	
180	7 feet	24	4 of 6 years each.	Allowance was made for thickness of bark during r ng countings.
180	7 feet	30	5 of 6 years each.	
165	7 feet	20	5 of 4 years each.	
180	7 feet	30	5 of 6 years each.	
150	7 feet	30	5 of 6 years each.	
180	7 feet	30	5 of 6 years each.	On poor localities, exploitable girth 6 feet. On better localities exploitable girth 7 feet. Average for whole reserve.
180	7 feet	30	5 of 6 years each.	On poor localities, the explo table girth is 6 feet.
160	6 feet	32	4 of 8 years each	On suitable local.t.es the exploitable girth is 7 feet.
150	7 feet	30	5 of 6 years each.	
150	7 feet	30	5 of 6 years each.	
150	7 feet	30	6 of 5 years each.	
173	7 feet	40	5 of 8 years each.	On poor localities, exploitable girth 6 feet. On better localities, exploitable girth 7 feet. Average for whole reserve.
200	7 feet	20	4 of 5 years each.	
..	7½ feet in moist and 6½ feet in dry forest.	20	..	
160	6′ dry 7′ moist	32	4 of 5 years each and 2 of 6 years each.	

APPEN

Statement showing rate of growth of teak in natural forest,

Forest Circle.	Forest Division.	Name of Forest.	Average age of tree of girth of			
			3′	4½′	6′	7′
Pegu .	Prome . . .	Shwelè	65	91	124	148
	Ditto . . .	Nawin	60	90	131	160
	Zigôn . . .	Kangyi	50	65	85	110
	Ditto . . .	Gamôn†	66	104	147	165
	Ditto . . .	Bawbin†	66	100	152 dry ..	.. 160 moist
	Ditto . . .	Taungnyo† . . .	Dry 51 Moist 60	80 93	154 ..	.. 159
	Tharrawaddy . .	Thônzè†	Dry 47 Moist 47	82 68	131 101	149 130
	Ditto .	Kadinbilin† . . . Kônbilin† . . .	49	83	123 dry ..	.. 130 moist
	Ditto . .	Môkka†	47	81	123	165 137
	Ditto . .	Minhla†	66	104	157 dry ..	.. 170 moist
	Ditto .	Satpôk . . . . Sitkwin . . . . Thindawyo . . .	50	70	90	110
	Rangoon . . .	Plains	57	81	115	..
	Ditto . . .	Hills	52	83	114	134
	Pegu . . .	South Zamayi . .	49	81	117	145

DIX III—*contd.*

exploitable age and size and other particu'ars—contd.

Exploitable age adopted or rotation (years).	Exploitable size (ordinary minimum girdling limit of girth).	PERIOD AND SUB-PERIODS OF WORKING UNDER THE WORKING-PLAN. Period.	Sub-periods.	REMARKS.
		Years.		
150	6′ dry 7′ moist	30	5 of 6 years each.	
150	6′ dry 7′ moist	30	5 of 6 years each.	
120	7 feet	30	1 of 6 years* and 6 of 4 years each.	* A provisional felling-cycle for the extraction of over-mature trees of large size.
175	Under 6′ dry. Under 7′ moist.	35	5 of 7 years each.	
160	6′ dry 7′ moist	30	6 of 5 years each.	† In these working-plans the trees are arranged in diameter classes, and figures have here been corrected to correspond to the girth classes shown.
166	6′ dry 7′ moist	30	5 of 6 years each.	
150	6′ dry 7′ moist	30	6 of 5 years each.	
150	6′ dry 7′ moist	30	5 of 6 years each.	
150	6′ dry 7′ moist	30	6 of 5 years each.	
150	6′ dry 7′ moist	30	5 of 6 years each.	
175	6′ dry 7′ moist	35	5 of 7 years each.	
120	7 feet	30	5 of 6 years each.	
Not estimated.	6 feet	20	..	
150	6′ dry 7′ moist	30	5 of 6 years each.	
150	6′ dry 7′ moist	30	5 of 6 years each.	

APPEN

Statement showing rate of growth af teak in natu ral forest

Forest Circle.	Forest Division.	Name of Forest.	Average age of tree of girth of			
			3′	4½′	6′	7′
Tenasserim	Toungoo . . .	Kabaung . . .	63	96	137	167
	D tto . . .	Bondaung . . .	70	105	146	175
	Ditto . . .	West Swa, Sabyin and Lonyan.	56	82	115	143
	Ditto . . .	Gwethé . . .	57	86	117	139
	Ditto . . .	Saing Wg. Circle . .	59	86	116	142
	Ditto . . .	Kyaukmasin . .	75	114	155	186
	Ditto . . .	Pyu-chaung and Pyu-Kun.	57	89	128	155
	Shwegyin . . .	Nyaunglebin Wg. Circle .	57	90	132	163
	Ditto . . .	Tonkan . . .	Countings were not made.			
	Thaungyin . .	Lower Thaungyin Wg. Circle.	59	92	137	167

DIX III—*concld.*

exploitable age and size and other particulars—concld.

Exploitable age adopted or rotation (years).	Exploitable size (ordinary minimum girdling limit of girth).	PERIOD AND SUB-PERIODS OF WORKING UNDER THE WORKING-PLANS.		REMARKS.
		Period.	Sub-periods.	
		Years.		
180	7 feet	30	5 of 6 years each.	
180	7 feet	30	5 of 6 years each.	
160	6′ dry 7′ moist	32	4 of 5 years each and 2 of 6 years each.	
150	7 feet	30	6 of 5 years each.	
150	7 feet	30	5 of 6 years each.	
196	7 feet	28	4 of 7 years each.	
165	7 feet	33	1st 3 of 5 years each and last 3 of 6 years each.	
180	7 feet	30	5 of 6 years each.	
180	7 feet	30	5 of 6 years each.	Girdling limit 8 feet in accessible localities where trees are vigorous, and 6 feet in poor localities.

APPEN

Statistics regarding Yield and

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	Estimated annual Yield.		Dates of sub-periods.	Results of	
			Total No. of trees.	Average per square mile of teak-bearing forest (No. of trees).		Estimate of yield for each sub-period.	Actual trees girdled.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Northern .	Katha .	Mohnyin .	1,500	45	I 1895-6—1899-1900	7,500	3,979
					II 1900-1—1904-5	7,500	3,929
	Myittha .	Kale Wg. Circle	3,000	17†	..	..	..
			1,300	7‡	..	..	..
	Ditto .	Taungdwin .	1,000	9	..	..	..
	U. Chindwin.	Mawku Wg. Circle.	5,000	17	..	..	..
Southern .	Pyinmana.	Yeni . .	700	12	I 1897-8—1902-3 .	4,200	3,252
					II 1903-4—1908-9 .	4,200	3,611
	Ditto .	Minbyin . .	1,700	9	I 1899-1900—1904-5	10,200	8,567
	Ditto .	Yonbin . .	1,000	9	I 1900-1—1905-6 .	6,000	5,425
	Ditto .	Ngalaik . .	1,350	11	I 1902-3—1907-8 .	8,100	6,875
	Ditto .	Yanaungmyin, Kaing and Palwe.	1,200	6	I 1903-4—1908-9 .	7,200	7,613
	Ditto .	Taungnyo .	475	5	I 1903-4—1908-9 .	2,850	2,953
	Ditto .	Ziyaing-Mehaw.	400	21	I 1903-4—1907-8 .	2,000	..
	Ditto .	Sinthe . .	550	5	..	..	..
	Ditto .	Pozaungdaung.	425	5	..	..	..
	Ruby Mines	Nanhan, Nampaw and Subôk.	700	5	..	..	..
	Ditto .	Maingtha, Kun-Chaung and Naume.	2,000	6	..	..	..

[1] For completed

DIX IV.

Outturn of Burma Teak Forests.

ACTUAL WORKING.[1]							
	No. of Logs yielded.		Volume in cubic feet.		Average volume per log, cubic feet.		Remarks.
Trees felled (girdled and ungirdled).	Logs.	Refuse timber.	Logs.	Refuse timber.	Logs.	Refuse timber.	
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
7,265	7,004	..	369,366	..	53	..	
4,014	11,391	..	741,632*	..	65	..	* The number of pieces of refuse timber yielded in the years 1903-4 and 1904-5 is not given, only the volume 13,683 cubic feet being shown in the Control forms: this is not included in the 741,632 cubic feet shown here.
..	..	..	..	..	..	..	† In first period of 20 years.
..	..	..	..	..	..	..	‡ In second period of 32 years.
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
2,763	24,148§	..	847,062§	..	35	..	§ The volume of 4,748 logs yielded in the year 1902-3 not being given in the Control form, this is not included in the 24,148 logs shown here.
5,566	34,095‖	1,095	1,360,877‖	51,965	40	47	‖ The volume of 4,187 logs yielded in the year 1903-4 not being given in the Control form, this is not included in the 34,095 logs shown here.
6,359	15,394¶	462	567,174¶	14,016	37	30	¶ The volume of 4,069 logs yielded in the year 1903-4 not being given in the Control form, this is not included in the 15,394 logs shown here.
574	6,982	6,585	369,039	138,437	53	21	
33	6,784	..	206,864	..	30	..	
6,181	28,317**	192	547,176**	5,556	19	29	** The volume of 2,270 and 7,630 logs yielded in 1906-7 and 1907-8, respectively, and the number of logs, of which 73,391·46 is the volume yielded in 1908-9, not being given in the Control forms, these are not included in the 28,317 logs and 547,176 cubic feet shown here.
..	4,822	..	122,916	..	25	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	

sub-periods only.

APPEN

Statistics regarding Yield and

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	Estimated Annual Yield. Total No. of trees.	Estimated Annual Yield. Average per square mile of teak-bearing forest (No. of trees).	Dates of sub-periods.	Results of: Estimate of yield for each sub-period.	Results of: Actual trees girdled.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Southern .	Pyinmana .	Hintha Wg. Circle.	300	2·4	..	..	..
	Minbu .	Taungdwingyi .	..	..	..	..	..
Pegu .	Thayetmyo	East Yoma, Satsuwa and Tindaw.	1,000	8	..	..	..
	Prome .	Shwele . .	1,000	9	I 1892-3—1897-8 .	6,000	6,376
					II 1898-9—1903-4 .	6,000	5,137
	Ditto .	South Nawin .	2,400	11	I 1893-4—1898-9 .	6,600	6,477
					II 1899-1900—1904-5	6,600	6,232
		Chaungzauk .			I 1893-4—1898-9 .	4,200	4,030
					II 1899-1900—1904-5	4,200	2,945
		North Nawin .			I 1893-4—1898-9 .	3,600	4,490
					II 1899-1900—1904-5	3,600	3,597
	Zigôn .	Kangyi . .	130	16	1892-3—1897-8 (Provisional rotation).	780	856
					I 1898-9—1901-2 .	520	502
					II 1902-03—1905-6 .	520	531
	Ditto .	Gamon . .	1,000	14	I 1888-9—1894-5 .	7,000	7,509
					II 1895-6—1901-2 .	7,000	4,239
					III 1902-3—1908-9 .	7,000	6,058
	Ditto .	Bawbin . .	1,600	14	I 1890-1—1894-5 .	8,000	6,899
					II 1895-6—1899-1900	8,000	5,383
					III 1900-1—1904-5 .	8,000	9,327

DIX IV—*contd.*

Outturn of Burma Teak Forests—contd.

ACTUAL WORKING. Trees felled (girdled and un-girdled).	No. of Logs yielded. Logs.	Refuse timber.	Volume in cubic feet. Logs.	Refuse timber.	Average volume per log, cubic feet. Logs.	Refuse timber.	Remarks.
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
4,315	6,071	..	368,364	..	61	..	* The volume of 743 logs yielded in the year 1903-4 not being shown in the Control form, this is not included in the 10,746 logs shown here.
6,908	10,746*	..	729,320*	..	68	..	
3,344	2,300†	..	144,123†	..	63	..	† The volume of 806 logs yielded in the years 1894-5 and 1895-6 not being shown in the Control forms, this is not included in the 2,300 logs shown here.
6,225	4,820‡	..	325,265‡	..	67	..	‡ The volume of 1,538 logs yielded in the year 1903-4 and the number of logs of which 56,525 cubic feet is the volume yielded in the year 1904-5 not being shown in the Control forms, these are not included in the 4,820 logs and 325,265 cubic feet shown here.
332	130	..	7,794	..	60	..	
1,027	766§	..	43,663§	..	57		§ The volume of 121 logs yielded in the year 1903-4 not being shown in the Control form, this is not included in the 766 logs shown here.
1,206	681	..	41,912	..	62	..	
3,836	1,543‖	..	103,200‖	..	67	..	‖ The volume of 1,080 logs yielded in the year 1903-4 and the number of logs of which 82,250 cubic feet is the volume yielded in the year 1904-5 not being given in the Control forms, these are not included in the 1,543 logs and 103,200 cubic feet shown here.
559	606	..	30,300	..	50	..	
703	1,102	226	86,826	6,614	79	29	
565	639	2,800	65,935	86,975	103	31	
7,654	10,603	..	530,150	..	50	..	
12,266	13,861	1,102¶	866,633	25,532¶	63	23	¶ The number of pieces of refuse timber yielded in the year 1899-1900 is not given, only the volume 20,830 cubic feet being shown in the Control form ; this is not included in the 25,532 cubic feet shown here.
5,902	7,656	6,922	549,776	175,589	72	26	
10,686	16,532	..	826,600	..	50	..	
12,581	15,405	..	1,033,611	..	67	..	
8,346	10,770	5,073	789,816	145,039	73	2	

APPEN

Statistics regarding Yield and

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	Estimated Annual Yield. Total No. of trees.	Average per square mile of teak-bearing forest (No. of trees).	Dates of sub-periods.	Results of: Estimate of yield for each sub-period.	Actual trees girdled.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pegu	Zigôn	Taungnyo	2,000	12	I 1891-2—1896-7	12,000	12,000
					II 1897-8—1902-3	12,000	12,442
					III 1903-4—1908-9	12,000	10,566
	Tharrawaddy.	Thonzè	1,000	12	I 1884-5—1888-9	5,000	..
					II 1889-90—1893-4	5,000	2,100
					III 1894-5—1898-9	5,000	3,681
					IV 1899-1900—1903-4	5,000	5,000
					V 1904-5—1908-9	5,000	4,957
	Ditto	Kadin-bilin	1,000	16	I 1885-6—1890-1	6,000	6,000
					II 1891-2—1896-7	6,000	6,000
					III 1897-8—1902-3	6,000	5,527
					IV 1903-4—1908-9	6,000	6,614
		Kôn-bilin	250	13	I 1885-6—1890-1	1,250	1,561
					II 1891-2—1896-7	1,250	928
					III 1897-8—1902-3	1,250	348
					IV 1903-4—1908-9	1,250	1,239
		Môkka	350	9	I 1885-6—1890-1	2,100	1,577
					II 1891-2—1896-7	2,100	1,598
					III 1897-8—1902-3	2,100	1,383
					IV 1903-4—1908-9	2,100	1,534
	Ditto	Minhla	500	12	I 1888-9—1894-5	3,500	2,219
					II 1895-6—1901-02	3,500	2,714
					III 1902-3—1908-9	3,500	2,793
	Ditto	Satpôk	165	21	..	..	..
		Sitkwin	30	15	..	..	..
		Thindawyo	33	3	..	..	..

DIX IV—*contd.*

Outturn of Burma Teak Forests—contd.

ACTUAL WORKING.			VOLUME IN CUBIC FEET.		AVERAGE VOLUME PER LOG. CUBIC FEET.		REMARKS.
Trees felled (girdled and un-girdled).	NO. OF LOGS YIELDED.						
	Logs.	Refuse timber.	Logs.	Refuse timber.	Logs.	Refuse timber.	
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
13,182	18,111	..	1,004,752	..	55	..	
11,034	13,716	797	1,259,789	21,170	92	27	
9,532	10,881	9,105*	975,299	225,694*	90	25	* The number of pieces of refuse timber yielded in the years 1904-5 and 1908-9 is not given, only the volume 52,760 cubic feet being shown in the Control forms; this is not included in the 225,694 cubic feet shown here
..	..	..	..	..	..	..	Figures not available
6,258	8,288	..	414,400	..	50	..	
4,854	6,642	..	420,826	..	63	..	
3,571	3,506	..	235,957	..	67	..	
3,699	3,884	2,141	246,606	55,868	63	26	
3,831	5,746	..	262,080	..	46	..	
10,307	10,937	..	602,171	..	55	..	
8,365	8,714	..	541,860	..	62	..	
5,995	7,387	297	534,928	9,328	72	31	
696	1,707	..	73,790	..	43	..	
2,807	2,600	..	144,277	..	55	..	
394	878	..	32,783	..	37	..	
1,168	1,567	334	94,408	7,552	60	23	
2,148	2,050†	..	102,500†	..	50	..	† The number of logs yielded in the years 1887-8 and 1888-9 is not given, only the volume 31,650 cubic feet being shown in the Control form ; this is not included in the 102,500 cubic feet shown here.
2,828	2,383	..	142,396	..	60	..	
1,921	2,469	..	157,570	..	64	..	
1,552	1,942	511	127,446	13,443	66	26	
4,850	6,578	..	328,190	..	50	..	
2,994	4,429	..	292,748	..	66	..	
3,375	4,937	962‡	312,699	23,616‡	63	25	‡ The number of pieces of rufuse timber yielded in the year 1904-5 is not given, only the volume 25 cubic feet being shown in the Control form; this is not included in the 23,616 cubic feet shown here.
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	

APPEN

Statistics regarding Yield and

Forest Circle.	Forest Division.	Name of Forest or Working Circle.	Estimated annual Yield.		Dates of sub-periods.	Results of	
			Total No. of trees.	Average per square mile of teak-bearing forest (No. of trees.)		Estimate of yield for each sub-period.	Actual trees girdled.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pegu .	Rangoon .	Plains . .	120	2	..	..	..
	Ditto .	Hills . .	1,400	7	..	..	..
	Pegu .	South Zamayi .	1,350	6	..	..	..
Tenasserim	Toungoo .	Kabaung .	1,800	6	I 1894-5—1899-1900	10,800	10,800
					II 1900-1—1905-6 .	10,800	11,370
	Ditto .	Bondaung .	650	18	I 1894-5—1899-1900	3,900	3,900
					II 1900-1—1905-6 .	3,900	3,901
	Ditto .	West Swa, Sabyin and Lonyan.	1,000	7	I 1897-8—1901-2 .	5,000	6,209
					II 1902-3—1906-7 .	5,000	2,777
	Ditto .	Gwethe . .	600	12	I 1899-1900—1903-4	3,000	2,904
					II 1904-5—1908-9 .	3,000	2,701
	Ditto .	Saing Wg. Circle	1,650	10	I 1899-1900—1904-5	9,900	8,755
	Ditto .	Kaukmasin .	400	10	I 1898-9—1904-5 .	2,800	1,839
	Ditto .	Pyu-Chaung and Pyu-Kun.	3,500	8	I 1902-03—1906-7 .	17,500	16,163
	Shwegyin .	Nyaunglebin Wg. Circle.	3,800	7	..	..	..
	Ditto .	Tonkan . .	..	..	..	..	..
	Thaungyin	Lower Thaungyin Wg. Circle.	1,000	..	..	..	..

DIX IV—*concld.*

Outturn of Burma Teak Forests—concld.

ACTUAL WORKING.			VOLUME IN CUBIC FEET.		AVERAGE VOLUME PER LOG, CUBIC FEET.		REMARKS.
Trees felled (girdled and un-girdled).	NO. OF LOGS YIELDED.						
	Logs.	Refuse timber.	Logs.	Refuse timber.	Logs.	Refuse timber.	
(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
5,253	4,732	..	317,883	..	67	..	
17,018	20,768	..	1,376,829	..	66	..	
1,951	..	..	..	..	..	..	
4,679	4,018	..	245,236	..	61	..	
3,320	1,663	..	96,021	..	58	..	
7,153	6,945	..	472,723	..	68	..	
2,002	602	..	32,860	..	55	..	
2,194	3,869	..	235,848	..	61	..	
7,527	7,046	..	415,086	..	59	..	
3,402	2,646	..	145,107	..	55	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	
..	..	..	..	..	..	..	

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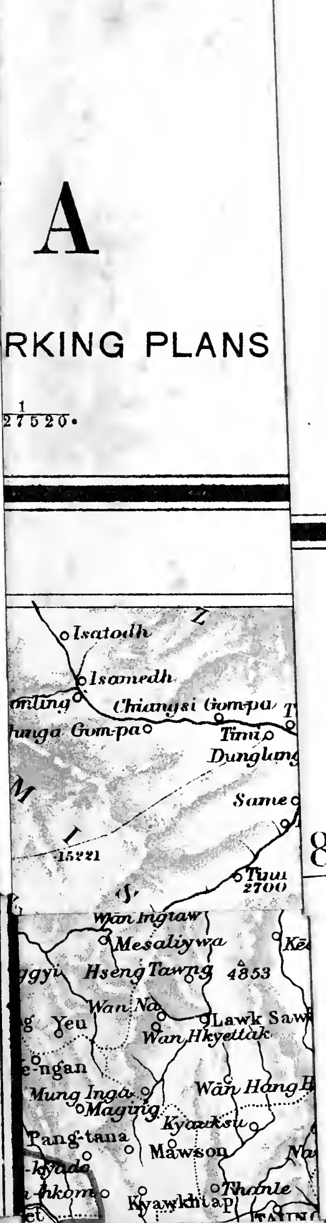
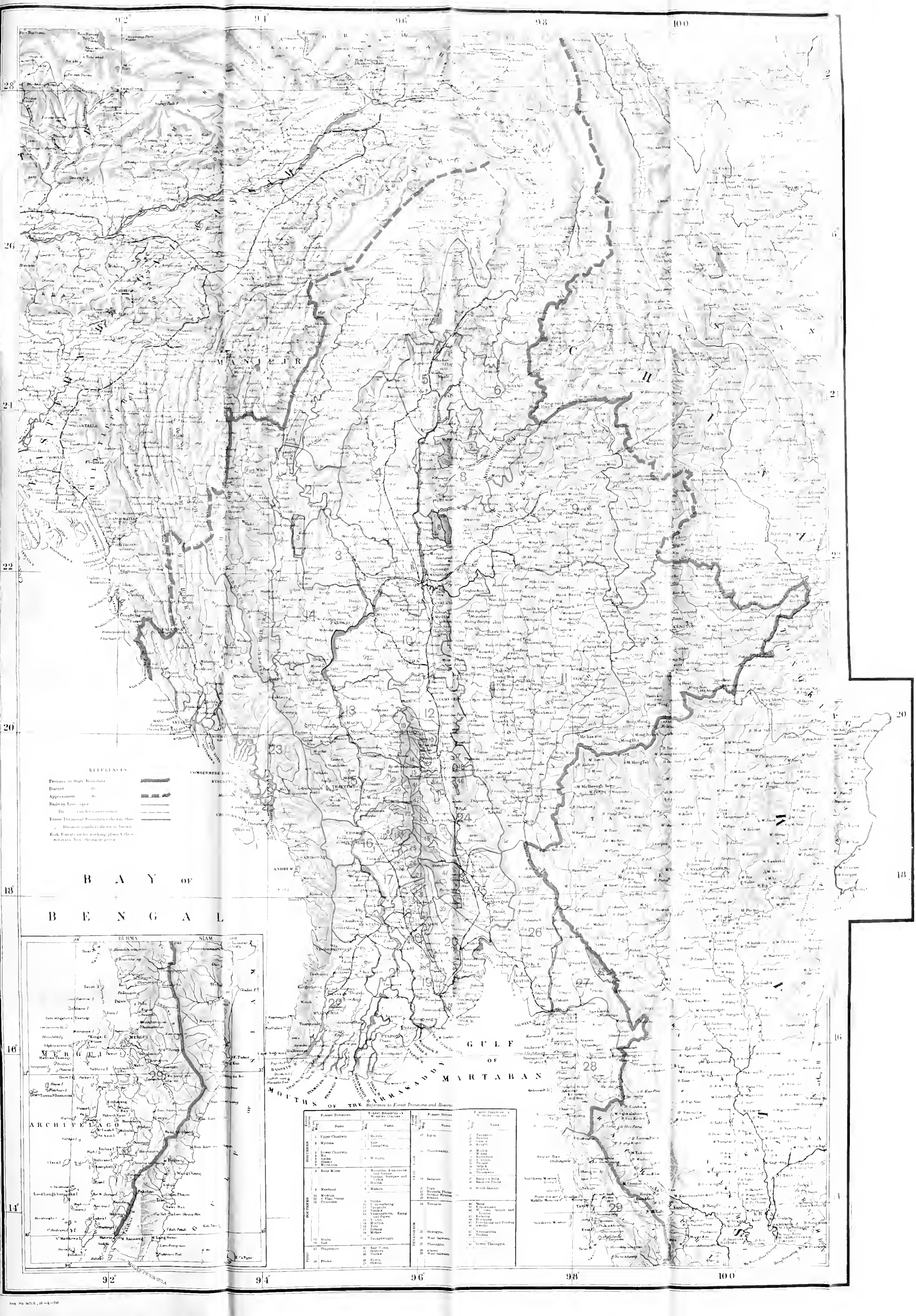


BURMA

SHEWING TEAK FORESTS UNDER WO[R]KING PLANS IN 1910.



INTRODUCTION.

THIS Note on the Antiseptic Treatment of Timbers has been prepared with a view of briefly reviewing all past experiments made in this connection in India, especially with reference to sleeper timbers; to record the results of the experiments made at the Imperial Forest Research Institute during the last two years with a variety of antiseptic solutions; and to lay down the lines on which it is proposed to conduct further enquiry on this subject.

Chapter I deals with the present position of affairs in India, with special reference to the antiseptic treatment of sleeper woods, a brief summary of the possible methods of treatment, and timbers suitable for sleepers. Chapter II discusses the various processes of injection by pneumatic and hydrostatic agencies. Chapter III deals with the Open Tank and Brush Methods of treating timber, and Chapter IV is a short *resumé* of the work which it is proposed to carry out in the future.

Where reports or other documents have been quoted in the body of the Note, the names of the authors, where possible, have been given. The writer's best thanks are due for advice and help given by Professor Henry, Deputy Director of the International Forest School at Nancy, to Hauptmann Basilieus Malenković of the Austrian Royal Engineers, and to the Chief Engineer, Western Australian Government Railways.

LIST OF PUBLICATIONS AND REPORTS ON THE ANTISEPTIC TREATMENT OF TIMBER.

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2. Memorandum on the supply of railway sleepers of the Himalayan Pines suitable for impregnation in India—by Sir D. Brandis (Inspector General of Forests. Proceedings, October 1878).

3. Impregnation of Himalayan pine-wood for use as railway sleepers.—Government of India, Department of Revenue, Forests. Proceedings Nos. 8 to 10, May 1879.

4. Preservation of timber.—Indian Forester, 1881, Vol. VI, page 142.

5. The Antiseptic Treatment of Timber.—Indian Forester, 1884, Vol. X, page 582.

6. The Preservation of Timber.—Indian Forester, 1886, Vol. XII, pages 127-137.

7. Methods of Preserving Timber in Japan.—Indian Forester, 1886, Vol. XII, page 527.

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Note on the Antiseptic Treatment of Timber in India, with special reference to Railway Sleepers.

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CHAPTER I.

Preliminary Note on the Antiseptic Treatment of Timber.

(1) THE PRESENT POSITION OF THE ANTISEPTIC TREATMENT OF TIMBER IN INDIA.

PAST HISTORY IN INDIA.

AS long ago as 1854 it was considered necessary to discover a process by which the inferior species of timber, procurable from the forests of India, could be treated with a view to prolonging their life. To attain this object the East Indian Railway about that time erected a Creosoting plant at Bally near Howrah, which, however, appears not to have remained long in existence.

From that time onwards much attention has been paid to the subject, notably by the erection at various times and in different parts of the country of such plants embodying the Burnettizing, Haskinizing, Creosoting, and Powellizing processes, as also by the Boucherie system.

In 1878, the Government of India deputed Dr. Warth, an official who had given much time to the study of this subject, to make a detailed enquiry into the possibility of treating the conifer woods of the Himalayas so as to render them suitable for sleepers. The result of this

officer's enquiry was a valuable report, in which he laid down a scheme for treating coniferous timbers with chloride of zinc and sulphate of copper. His proposals, however, were never carried through.

The various plants working according to different methods, which were erected in the sixties, were for one reason or another all discontinued, so that in spite of all the attention paid to this subject and the large sums of money expended in experiments during the last 50 years, it may be said that, though the results are instructive and the records valuable, the practical results are *nil*.

One has only to glance at Appendices B and F of the Report of the International Railway Congress of 1902 on the causes of the deterioration of wooden sleepers or cross-ties, to see that all the great railway systems of India use untreated sleepers, with the exception of the Bombay, Baroda and Central India, the Bhavnagar-Gondal and Morvi Railways, who either use tarred or creosoted sleepers or both. The extended use of antiseptics for the preservation of sleepers has therefore still to be introduced into India.

To account for this backward state of affairs in India is by no means easy, considering that in Europe and America practically all railways use treated sleepers. Were the suitable timbers produced by the forests of India so plentiful, cheap and of such excellent quality as to render unnecessary the employment of artificial means for their preservation, the matter would require no further consideration, but this is not the case. It is true that most excellent sleeper woods such as Teak, Sal, Pyinkado and Deodar do occur in great quantities in the State Forests but even 30 years ago the price of these timbers was high, while now Teak can be sold in the log at prices which render it, when converted into sleepers, too expensive for railway requirements. The other species are still largely on the market as sleeper woods, though in most cases their price is not far below the working limit, especially that of Sal.

POSITION OF THE MARKET.

Another consideration is the possible annual output as compared with the present and future demand. The requirements of the Railway systems of India, for new construction, as also for replacing worn out sleepers are very large. It is difficult to estimate the relative position of the possible supply as compared with the present and prospective demand, hence it is proposed to limit the scope of this note to existing conditions.

The present tendency of the Railway Companies is to import Australian Jarrah and Karri sleepers, as well as Baltic Creosoted Pine and this is without doubt due to the high prices of the 1st class sleeper woods obtainable in India and possibly to the shortage in supply and not to the quality of Teak, Deodar, Pyinkado and Sal sleepers.

AUXILIARY SPECIES.

The utilization of our so-called "inferior species" is another plea in favour of the introduction of the antiseptic treatment of these timbers. Under this head are classed all timbers other than the four species already mentioned. Of these "inferior species," which should more properly be termed "auxiliary species," many are unfit for sleepers owing to their inability to withstand the wear and tear to which they would be subjected, while others are not found in sufficient abundance to make them worthy of consideration. There remain a certain number of species which owing to their abundance and technical quantities are suitable, but which owing to their liability to the attacks of insects and fungi, cannot be classed as really good sleeper timbers. A complete list of such timbers will be considered later; sufficient is it to say that it was to those species that Sir Dietrich Brandis referred in his report, dated 21st October 1878, on this subject and which Dr. Warth had in his mind when he drew up his scheme in 1878 for erecting a plant for treating such species with chloride of zinc and sulphate of copper. In 1905, Mr. F. D. Couchman, drew up a memorandum on the subject, as also did Mr. Eardley-Wilmot, the late Inspector-General of Forests. Both these officers advocated the necessity of the more extensive utilization of these auxiliary species. Lastly, the Advisory Committee of the Royal Society in their letter to the India Office, dated 18th March 1909, represented the urgency of collecting all available data on this subject and pointed out the necessity of laying down definite lines along which enquiry should be conducted.

Enough has been said above to illustrate the importance of this subject and the amount of attention that has already been given to it by the Government, the Railway authorities, and other interested parties both in India and in Europe.

(2) SUMMARY OF THE PRESENT METHODS OF TREATING TIMBER WITH ANTISEPTICS.

It is here only proposed to give a summary of the processes now in use and to briefly compare their relative values one with another. In

Chapters II and III a more detailed description is given of each process, together with any available data of past records as to its value and a note on the suitability of the process in India.

CAUSE OF THE EXTENSION OF THE ANTISEPTIC TREATMENT OF TIMBER.

The position of affairs in the Indian timber market is very similar to that in many other countries of the world. Owing to the ever increasing population and to the corresponding increase in trade and therefore to the greater demand for timber, both for private, industrial and railway purposes, the possible supply of suitable sleeper timbers has been seriously challenged, and the prices have steadily risen, until purchasers have been forced to consider possible substitutes or even to take to materials other than timber to meet their requirements. Though this was the condition of affairs in many countries as long ago as the middle of the last century, the position has by no means improved ; in fact it has become more and more acute.

To overcome the difficulties which might be caused by a possible timber famine, the idea has been to prolong the life of timber by treating it with some antiseptic solution and so to render it immune to the ravages of insects and fungi. With this object in view various antiseptic solutions have from time to time appeared on the market, and either the method of treatment or the solution used, or both, have been protected by the Patent Acts of various countries.

VARIOUS METHODS OF TREATING TIMBER.

The various processes invented for the antiseptic treatment of timbers fall naturally under two main heads, (i) those in which an extensive plant is required to effect the hydrostatic or pneumatic injection of the solution, and (ii) the open tank or immersion process.

Into the first category came such well-known processes as Creosoting, Haskinizing or Vulcanizing, Burnettizing, Gardnerizing as also the Boucherie and Rüping processes, or the more simple method of immersing the timber in an antiseptic solution either at a normal or a high temperature. Under the latter head the number of patent solutions which have from time to time been brought on the market and which are used in the open tank process, is very large. The first preservatives which appeared are probably *Avenarius Carbolineum* and *Corrosive sublimate* or the *Kyanizing* process ; among others may be men-

tioned *Powellizing,* in which a saccharine solution is used, *Jodelite, Solignum, Atlas, Bêllit, Bêllitol, Microsol, Hylinit, Crésoyle, Green-oil, Mort-ant, Anthrol,* and a compound of *Zinc-chloride* and *Sodium-fluoride.*

RELATIVE VALUE OF THE PNEUMATIC AND VULCANIZING PROCESSES AS AGAINST THE OPEN TANK METHOD.

Before discussing the relative merits of any one of the above methods of treating timber it is necessary to consider the value, with reference to India, of the Pneumatic and Vulcanizing processes as compared with Open Tank or Brush Methods.

In the case of Creosoting, Haskinizing or Rüpingizing timber a fairly extensive plant is necessary and therefore a corresponding outlay of capital. This being the case, it is only possible to have a limited number of centres scattered over the country at which timber can be treated. Such centres would either be situated in a convenient place near extensive forest areas, or in localities where timber is in large demand and to which large quantities are imported. In localities where it is contemplated to treat railway sleepers, it might be possible to erect a plant in the vicinity of the forests and at the same time not far from the railway; in such a case the difficulty of either railing the timber to be treated over a long lead or of transporting the treated timber a long distance to the rail, would be overcome. In India proper it not infrequently occurs that the forests are scattered over large areas and that the work of extraction moves forward through the forest, so that the same difficulty which has been experienced with non-portable sawmills for converting the timber, applies with even more force to the more extensive and heavier plant necessary for treating timber by Pneumatic or Hydrostatic injection.

Without a doubt convenient centres could be found where the supply of timber is naturally concentrated in very large quantities on a railway and where an extensive plant of the sort contemplated might be worked. In corroboration of such an assertion such places as the nearest station below the junction of the Tons and Jumna rivers in the United Provinces might be cited, or again a timber centre such as Kallai near Calicut in the Malabar, points on the Sutlej and Bias River in the Punjab, and Mandalay or Rangoon in Burma. Nevertheless, the difficulties to be overcome in contemplating such schemes are considerable, though the process in itself may be excellent.

Turning to the Open Tank or Brush methods the difficulties as to plants are naturally small. All that is required is an iron or zinc tank either placed over an open hearth or fitted inside with steam pipes to heat the solution. As the locality of extraction or the place of supply changes, the whole plant can be cheaply and easily moved or an entirely new plant erected at a minimum outlay of capital, and it is for this reason,—the question as to the value of the actual antiseptic or process being eliminated for the time—that the Open Tank process commends itself so strongly for use in India.

Another essential difference between the Pneumatic or Hydrostatic and Open Tank methods is that in the former processes the timber affected throughout; in other words, the solution or vulcanization penetrates to the centre of the timber, whereas in the Open Tank in the treatment of hard-woods the solution only penetrates a short distance below the surface and so only forms a shell of protected tissue round the log, the depth of which will depend on the density of the fibre and the duration of immersion. With reference to India the relative value of complete or only partial treatment of the wood is as yet not fully known. Without doubt the processes which treat the timber throughout would appear to have the advantage; on the other hand, decay starts from the outside and if the outer layers remain properly protected for a reasonable period of time it would be difficult for fungi or insects to make headway into the centre of a log. Again, the place most liable to attack is the end of a log and by the Open Tank process the solution penetrates further in this direction than into the sides, and so gives greatest protection at the point most open to attack.

CHEMICALS IN USE FOR THE PREPARATION OF ANTISEPTIC SOLUTION.

Many tar-oils and acids, as also salts have been employed in the preparation of antiseptic solutions. The best known of these are Creosote, obtained by the distillation of coal tar; chloride of zinc; sulphate of copper; corrosive sublimate; bi-chloride of mercury used in the so-called "Kyanizing" process; a saccharine and arsenic solution used in Powellizing; fluorine compounds; and Dinitro-phenols. The various patent antiseptic solutions now found on the market such as *Avenarius Carbolineum, Atlas, Cresoyle, Crésol-calcium, Microsol, Bëllit, Bëllitol, Jodelite,* etc., are generally made up of one or other of the above substances.

CREOSOTE.

The most extensively used and probably oldest antiseptic is Creosote which, though undeniably effective, is expensive and will remain so in India until its preparation is carried out on an extensive scale in the country. Hauptmann Basilius Malenković of the Austrian Royal Engineers, and a great expert on the antiseptic treatment of timber, somewhat sarcastically remarks that it is claimed for Creosoting that it is a cheap method, as only 100 litres are now required for impregnating one cubic metre, whereas formerly 300 litres were required. Somewhat expensive as the process may be it is used all over Europe and to a considerable extent with the Open Tank method in America, while the only treated sleepers used on Indian Railways are of imported Creosoted Red-Pine. It is said that the Berlin Rütgerswerke maintain that Creosote is the only serviceable method of preserving railway sleepers. This is a sweeping statement, and would certainly not be accepted by many experts.

PRODUCTS OF CREOSOTE.

Tar yields (1) oils lighter than water, (2) oils heavier than water, and (3) pitch. The latter oils have been given the name of Creosote, though true Creosote is obtained from wood. These heavy oils contain Phenol or Tar acids such as Carbolic and Cresylic acid, of which a certain percentage is most necessary in good antiseptic solutions. They also contain Naphthalene, Quinolene, Leucolene, Crysene, Pyrene, Anthracene, etc. These Hydro-carbons are the base of many of the antiseptic solutions now on the market. Phenol unmixed with other substances is not a good antiseptic for the preservation of wood, as it has a low boiling point and is therefore liable to evaporate; its value with other substances is, however, indisputable, in fact it is one of the most essential ingredients for a good antiseptic solution, for it has been recognised that it is partly owing to the presence of these acids that fungoidal growth is retarded. As above stated, the products of Creosote when mixed in various percentages have been given different names, amongst which may be mentioned Carbolineum oils; of these, the well-known antiseptic *Avenarius Carbolineum,* has long been in use. Crésoyle is another patent antiseptic made of these Hydro-carbons, while Crésol-Calcium, of recent invention, is a mixture of tar-acids with milk

of lime. Many other such solutions are in existence having as their base these Creosote oils.

Chloride of Zinc.

Chloride of Zinc obtained by dissolving metallic zinc in hydrochloric acid is nearly as extensively used as Creosote, but it has certain disadvantages, amongst which may be mentioned its corrosive action on iron, it is also highly hygroscopic, that is to say, it readily absorbs moisture, which not only reduces its strength but is liable to render the treated timber damp. To overcome this drawback Creosote has been added to the salt, and the treatment given the name of "Mixed impregnation". It has many good qualities, however, which have caused it to be so extensively used. Mr. Sherfesee, of the United States Forest Service, says that creosote and zinc-chloride are the only preservatives in common use in America. It is used to a fair extent on German Railways for impregnating sleepers and by the Telegraph Companies for treating their poles, but it is not so extensively employed as was formerly the case. Both Professor Henry, of the National Forest School at Nancy, and Hauptmann Basilius Malenković of Austria are not in favour of zinc-chloride alone, the latter officer saying that it cannot be compared with Creosote or fluoride solutions, though of value when mixed with other substances.

Sulphate of Copper.

Blue Vitriol or Sulphate of Copper used in Boucherie's and Margary's processes has according to Sherfesee, fallen into almost total disuse in America. It has the disadvantage of losing its antiseptic properties and is liable to be dissolved in water and so get washed out of the timber. Warth, in drawing up his report in 1878, advocated copper sulphate as it had been employed by the Lübeck-Buchen, Ost-Preussen-Berlin-Stettin and other Railways. This salt, however, has not been recommended by recent experts, and in India, where the treated timber is often subjected to much moisture, its use cannot be advocated. It is possible, however, that copper sulphate mixed with other substances may be of value as an antiseptic. For instance, a substance known as Microsol is on the market which is said to contain 70 per cent. of sulphate of copper, mixed with Phenol and sulphur compounds, and sulphate of lime. This patent solution is very strongly recommended by Professor Henry, an eminent expert on this subject. It is just possible that the gypsum forms a

deposit on the cells of the wood enclosing the copper-sulphate in the tissue and so overcomes the objection to which this salt is liable, *i.e.* being washed out of the impregnated timber.

CORROSIVE SUBLIMATE OR BICHLORIDE OF MERCURY.

Corrosive sublimate is still used to a limited extent in some countries and its action is without doubt efficacious, but the sublimate is expensive and its poisonous properties a serious drawback. Further Mr. Howard F. Weiss of the American Forest Service states that the process is of such long duration that it cannot be recommended. It is used extensively for preserving wood and seed specimens for museums. In Germany it is used for preserving telegraph posts, and there still remain in New England two plants where this substance is employed. Warth in his report (para. 4) advocates its use in India but only as an experiment. Looking to its cost and poisonous properties it cannot be recommended, especially as equally good and cheaper preservatives are procurable.

SACCHARINE SOLUTION.

The Saccharine solution used in the Powellizing process is new amongst antiseptics. It is supposed that arsenic is one of the ingredients, though the composition of this preservative is a secret. The effect of Powellizing has so far proved very successful; time alone can prove its value in India.

COMPOUNDS OF FLUORINE AND DINITRO-PHENOL.

In the Höttgar process, employed by the Rütgerswerken in Berlin sodium-fluor-silicates are used. These are not altogether suitable, being expensive and not very effective, while other fluor-silicates have the same disadvantages. For Military works in Austria, as also for telegraph posts, a solution of 3·25 k.g. of zinc to 100 litres of 3 per cent. Hydrofluoric acid has been used as an antiseptic. The salt (ZnF_2, 2HF) is prepared by a commercial firm, in a 20 per cent. solution only, so that to import to India 80 per cent. of water with which it is mixed would be expensive. Of all the pure Fluoride processes those recommended by Hauptmann Basilius Malenković, as applicable in this country, are mixtures of chloride of zinc and sodium-fluoride, and secondly Dinitrophenol. The mixture of $ZnCl_2$ and NaF when used in the Open Tank

process should be made into a concentrated solution, *i.e.*, 3·5 per cent. of each mixed with water and applied cold, the immersion of the timber lasting for 8 days. If a pneumatic plant is used a half strength solution can be employed. When utilizing the above salts great care should be taken that they are not adulterated with Na_2SiF_6, for such admixture renders the solution valueless.

Of the Dinitro substances may be mentioned (*a*) Bêllitol, which is a 2 per cent. solution of Dinitro-benzol and mineral oil, (*b*) Bêllit, which is made up at various strength and known as Bellit-Einfach and Bellit Doppel-fluor, being always a compound of sodium fluoride (Na, F.80 per cent.) and an organic salt of Dinitro-phenol or anilin Dinitro-phenol. These are cheap substances ; in fact mineral oil is cheaper than Creosote and Bêllitol is cheaper than either of these oils. Another great advantage is that Bêllit and Bêllitol are obtainable in the powdered form, so that only the concentrated solid ingredient of the solution has to be imported, thus enormously reducing the price as compared with the import of liquid solutions. The Captain further states that in his opinion they are as good, if not better than Creosote.

(3) POSSIBLE TIMBERS SUITABLE FOR RAILWAY SLEEPERS AFTER TREATMENT, OTHER THAN TEAK, SAL, DEODAR AND PYINKADO.

TECHNICAL CHARACTER OF TIMBER SUITABLE FOR SLEEPERS.

On page 3, sub-section " Auxiliary Species," it was stated that only certain timbers fulfilled the conditions necessary for sleepers. The most important factors are (i) that the present price of the timber together with the cost of treatment be less or at most not in excess of that of the best untreated sleeper woods, (ii) that they be procurable in large quantities, and (iii) that they be mechanically strong enough for the purpose. The first two conditions can be best determined by Forest Officers ; for a definite opinion on the last condition we must turn to expert engineers, and to past records. Mr. Couchman in his Note of 1905 lays down the necessary qualities required for sleepers as follows :—

" A timber to be suitable for railway sleepers must possess the following qualities :—

(*a*) It must be physically hard or tough enough to resist the cutting action of the rail or chair on its surface, and also the constant grinding action produced by traffic passing over it, packing of the road, etc.

(*b*) It must be capable of withstanding, for a reasonable number of years, the ravages of insects, fungoid growth, and the climatic influences to which it may be exposed."

As regards rule (*a*) cited above, it has been found that the wear and tear caused to soft-woods by the cutting action of the bed plate can, in a measure, be overcome by increasing the size of the bed plate, but even then the spike hole becomes enlarged. In America when soft-woods are employed, which with the help of an antiseptic can in themselves be made suitable for sleepers, the difficulty of the spike hole becoming enlarged and the bed plate wearing into the sleeper is sometimes overcome by letting in a hardwood plate at a point over which the bearing will come and driving in a dowel or plug of hardwood to receive the spike. These methods of preparing sleepers have proved fairly successful, but whether such a procedure would be accepted by the Indian Railways, who ask for extremely high standard of sleeper, is doubtful.

Rule (*b*) refers to the attacks of insects and fungi. Termites do considerable damage to sleepers; fungi also help largely towards their deterioration especially in damp localities, and it is to overcome these two methods of destruction that antiseptics are required. We may for the present eliminate the idea of doctoring the sleepers so as to bring them up to standard and rigidly adhere in the selection of our timbers for antiseptic treatment to the conditions laid down as to (i) Price, (ii) Possible output, and (iii) Mechanical fitness.

POSSIBLE SLEEPER WOODS.

The following is a list of timbers, excluding Teak, Sal, Deodar and Pyinkado requiring no treatment, which, it is thought, more or less meet these conditions and which are at present used to a certain extent as sleepers or might be used for this purpose, in any case which would be improved sufficiently by treatment to be classed as good sleeper timbers :—

I Most likely to fulfil the necessary requirements.	1. *Terminalia tomentosa.* 2. *Mesua ferrea.* 3. *Dipterocarpus alatus.* 4. *Dipterocarpus tuberculatus.* 5. *Pinus excelsa.* 6. *Pinus longifolia.*

II The next most likely species to fulfil the necessary requirements.	7. *Bischofia javanica.* 8. *Terminalia paniculata.* 9. *Lagerstrœmia microcarpa.* 10. *Lagerstrœmia Flos-Reginæ.* 11. *Lagerstrœmia parvifolia.* 12. *Lagerstrœmia tomentosa.* 13. *Hopea parviflora.*
III Possible Sleeper Woods.	14. *Picea Morinda.* 15. *Abies Pindrow.* 16. *Pinus Khasya.* 17. *Pœciloneuron indicum.* 18. *Vitex altissima.* 19. *Pterocarpus Marsupium.* 20. *Albizzia odoratissima.* 21. *Hardwickia binata.* 22. *Anogeissus latifolia.*

CLASS I.

TERMINALIA TOMENTOSA.

Terminalia tomentosa is found all over India and Burma having a very wide distribution, besides growing to a large size in many forests. The reports of Railway Engineers vary as to the quality of this timber for sleepers ; the majority estimate its life at 5 to 8 years

MESUA FERREA.

Mesua ferrea, the Nahor wood of Assam, is used on the Assam-Bengal, Dibru-Sadiya, Tezpur-Balipara Railways and has been used by the Madras Railways. The Dibru-Sadiya Railway gives it a life of from 8 to 10 years ; this is probably a somewhat high estimate. By laying down one thousand sleepers as an experiment on the South Indian Railway it was found that only one sleeper had decayed after 4 years.

DIPTEROCARPUS ALATUS.

There are practically no past records of *Dipterocarpus alatus.* It is, however, thought to be mechanically strong enough to be of use for sleepers and is found in sufficient quantities in Burma to yield a large number of ties annually.

DIPTEROCARPUS TUBERCULATUS.

The *In* wood of Burma is very common and also of fair durability. Untreated it is not sufficiently good for sleepers. The Agent, Burma Railway Co., reported that "In" had proved unsatisfactory and only lasted 3 to 4 years. It is mechanically hard enough for sleepers but not so hard that it would not readily absorb an antiseptic. This timber, if properly seasoned before pickling has a great future before it as a sleeper wood.

PINUS EXCELSA AND PINUS LONGIFOLIA.

The two Pines untreated, are entirely unsuitable for sleepers. About a thousand of each were laid down in 1907 in the line near Saharanpur as an experiment. They lasted from 27 to 30 months. The timber is procurable in large quantities from the Jumna and Tons forests, as also in the Punjab. That these Pine woods may answer for sleepers lies in the fact that they readily absorb antiseptics. The doubt is as to their fitness to withstand wear and tear.

In the second list all the species have been tried as sleepers, and many of them might rightly be put into the first list but for the reason that their distribution is either restricted or that though found in many parts of India they are not sufficiently numerous.

CLASS II.

BISCHOFIA JAVANICA.

Bischofia javanica is a very fair sleeper wood found in the sub-Himalayas from the Jumna eastward into Assam. Also found in the Carnatic and on the West Coast and all over Burma. It is fairly common in Assam but elsewhere sparsely scattered through the forest. It is used as a sleeper wood in Assam and on the Dibru-Sadiya Railway and is said to last at least 5 years untreated.

TERMINALIA PANICULATA AND LAGERSTRŒMIA MICROCARPA.

Terminalia paniculata has been tried for sleepers on the Madras and South Mahratta Railway and is given a life of 5 years; *Lagerstrœmia microcarpa* has not been much used for sleepers but is a good sound timber. In quality they are probably little inferior to the timbers of Class I, but their distribution is limited to the south of India and

especially to the West Coast, where in many localities they are abundant and grow to large trees with long straight stems.

LAGERSTRŒMIA PARVIFOLIA.

A large tree of most deciduous forests of India. Sleepers of this timber are mentioned in the International Railway Congress report as being used by the Assam and Bengal Railway. It is a hardwood and should be useful for sleepers after treatment.

LAGERSTRŒMIA TOMENTOSA.

Leza-wood is fairly durable and mechanically strong enough for sleepers. It is found scattered in the forests of Burma and the annual outturn is put at 6,000 tons or 80,000 B. G. sleepers. Had this species not been scattered over so great an area rendering the cost of extraction excessive, it would have found place in the first class.

HOPEA PARVIFLORA.

The *Irumbogam* of Madras and especially of Malabar is without doubt an excellent timber and nearly equal to Sal in quality. Its distribution is limited, though fairly plentiful in certain localities. The Madras Railway in classifying timbers suitable for sleepers placed Teak as first and Irumbogam as second, bracketed with Sal and Jarrah.

CLASS III.

In class III have been entered 10 species; objection may be taken to this arrangement, as for instance to *Vitex altissima* and *Pterocarpus Marsupium,* both excellent timbers, but, on the other hand, the quantity available from any one locality is relatively small. Again, the three conifers have been classed low down the list for the reason that their mechanical fitness is doubtful. Anjan (*Hardwickia binata*) sleepers have been reported as lasting 7 to 8 years, the timber seasons badly however and is extremely hard and difficult to saw; the same objections apply to *Anogeissus latifolia.* Of the other three, *Pœciloneuron indicum* is not very plentiful though a good timber, while *Albizzia odoratissima* has a wide distribution and is a fair timber but is not abundant.

CHAPTER II.

Process of Injection by Hydrostatic or Pneumatic Agency.

CHAPTER II.

Process of Injection by Hydrostatic or Pneumatic Agency.

(1) CREOSOTING.

CREOSOTING.

Creosoting is carried out by forcing the oil into the timber under pressure. It is one of the oldest methods of preserving timber employed in Europe and America and still to a great extent holds the field against other more recent inventions.

The process is briefly as follows: —

The converted timber to be treated is placed in iron cylinders to which is connected both a vacuum and pressure pump. When the work is carried out on a large scale the sawn material is packed on trucks, which, running on rails, are moved into the cylinders, and the rails removed when the retort has been filled, to allow the air-tight door being closed. The older method was then to subject the wood to a process of steaming which lasted about an hour, but this is now generally not carried out; instead, the timber is subjected to artificial drying in hot air chambers lasting 24 hours or more, before being treated with creosote. The process of artificial drying has to be carried out with care, as either heating to a temperature much over boiling point or prolonging the drying for too long a period is injurious to the timber. When the converted material has been artificially dried and put into the retorts a vacuum is created by means of the pump connected with the cylinder and what moisture may remain in the timber is extracted. The creosote is then forced into the retort by a pressure pump, at a temperature of 60° C to 70° C and kept at a pressure of

about 6 atmospheres for an hour or more. Boulton, quoted by Fisher, maintains that under his process, by which oil is forced into every fibre of the timber, sleepers are less liable to split owing to the temperature employed being higher than they are likely to be subjected to afterwards.

After treatment the fluid is drawn out of the cylinders into the reservoir and the trucks containing the creosoted wood removed.

Factors governing Effective Creosoting.

To render the process of Creosoting thorough and effective great care should be taken in seasoning the wood. It is most essential that it should be naturally well seasoned and, if necessary, further dried by artificial means.

Ancther most important point is the quality of the Creosote used. Tar is an extremely complex substance of organic compounds, varying according to the quality of the coal from which it is obtained, and further according to the way it is treated. Some tars, as for instance those from the Newcastle district, yield small quantities of carbolic and cresylic acids and contain more of those semi-solid substances which solidify within the pores of the timber, while others have more of those acids and contain a higher percentage of lighter oils, with a relatively low boiling point. The antiseptic properties of these acids is undisputed, thus a certain percentage of them in a solution is most desirable, but as they are not very stable, having a low boiling point and being readily soluble in water they cannot be relied upon for the preservation of timber unmixed with other substances. It is the heavy and less volatile portions of the Creosote oils to which one must look for the effective protection of the timber, in other words to those oils which have a relatively high boiling point, of 250° C. to 275° C. or even over.

Experiments carried out many years ago by Boulton pointed to the use of oils coming over at a high temperature, and the more recent results published by Mr. Gellert Alleman, Professor of Chemistry,

Swarthmore College, United States, based on his analysis of Creosoted timbers which had lasted for many years in exposed positions, also point to this conclusion.

Cases have occurred in India where imported Creosoted pine sleepers have failed within a relatively short period after being laid down, and this was probably due to faulty treatment, namely, that either the timber at the time of treatment was not properly dry, or that the Creosote was defective.

The amount of Creosote required to preserve the timber is governed by two factors, (i) the structure of the wood, (ii) the purpose for which the timber is being treated. In the first case woods of dense structure are incapable of absorbing the solution to the same extent as open textured soft-woods. Thus beech and pine woods are generally made to take up 10 lbs. per cubic foot, while harder wood, such as oak, takes up 3 lbs. per cubic foot. Again the purpose for which the timber is intended will govern the quantity necessary for its preservation. As an example it may be stated that for railway ties made of coniferous wood 10 lbs. per cubic foot is sufficient, while for jelly or pier-piles exposed to the action of marine borers, as much as 20 lbs. per cubic foot may be necessary. Hauptmann Malenković gives the proportion for averagely hard timbers as 100 litres per metre, or taking the specific gravity of Creosote at 1·05, 6·56 lbs. per cubic foot.

COST OF METHOD.

The cost of Creosoting timber must necessarily vary with the cost of Creosote at any given place and the amount of the solution absorbed by different species of timber. Dr. Warth states that from experiments made in 1854 with the plant set up at Bally near Howrah, *Sal* timber took up only 1 lb. per cubic foot, while *Sissoo* took up $3\frac{3}{4}$ lbs. per cubic foot. These are fairly hard woods, so that we may take an average wood as absorbing 6 lbs. per cubic foot and conifers and other soft woods at least 10 lbs. per cubic foot. Taking a broad gauge sleeper as containing 3·3 cubic feet, and the cost of Creosote as 7 annas per gallon, and its specific gravity 1·05 and the cost of labour for loading and unloading, etc., at 5 pies per sleeper, and firing, oil and other engine expenses

at 1 anna per sleeper, we get the cost of treating a broad-gauge sleeper exclusive of interest on capital and depreciation on plant as follows :—

SPECIES.	Amount of absorption by B. G. sleeper of 3·3 c. ft.	Cost of Creosote absorbed by a B. G. sleeper.	Cost of loading, labour, and engine expenses.	Total cost per B. G. sleeper.
		R a. p.	R a. p.	R a. p.
Hardwoods, such as *Terminalia tomentosa* and *Mesua ferrea.*	3 lbs. per cubic foot or a total of 9·9 lbs. per B. G. sleeper.	0 6 11	0 1 6	0 8 5
Moderately hard wood, such as *Dipterocarpus tuberculatus.*	6 lbs. per cubic foot or a total of 19·8 lbs. per B. G. sleeper.	0 13 10	0 1 6	0 15 4
Softwoods, such as *Pinus excelsa* and *Pinus longifolia.*	10 lbs. per cubic foot or a total of 33 lbs. per cubic foot.	1 7 1	0 1 6	1 8 7

Instances are given by Dr. Warth, in his report of 1878, as to the actual cost of Creosoting timbers in India. He quotes a report by the Superintending Engineer, Rajputana State Railway, on the work carried out with the plant erected at Aligarh in 1870. The estimated cost of the whole apparatus is given as R28,000 and the cost of treating *Pinus longifolia* B. G. sleepers as follows :—

	Per sleeper. R a. p.
$4\frac{3}{4}$ gallons of Creosote at Aligarh, at $6\frac{1}{2}$ annas per gallon .	1 15 0
Labour in stacking and loading sleepers at R5 per 1,000	0 0 10
Percentage of engine expenses	0 2 2
TOTAL	2 2 0

Another estimate is given for Creosoting Chir sleepers by Mr. Price, Superintending Engineer, Light Railway, North-Western Provinces, which runs as follows, per 100 sleepers :—

	R a. p.
350 gallons at 4 annas per gallon	87 8 0
Labour	2 8 0
Engine expenses	2 0 0
TOTAL .	92 0 0

In the first case the amount absorbed was 1·44 gallons per cubic foot, or taking a gallon of Creosote as 10 lbs., 14·4 lbs. per cubic foot and in the second case the absorption came to 9·5 lbs. per cubic foot. The present price of Creosote in Calcutta is 7 annas per gallon, so that based on the above calculations, but taking the current price of Creosote, the cost would be R2-4-3 or R1-10-1½ per B. G. sleeper of Chir pine. In the case of impregnation with 3 lbs. per cubic foot the cost of treatment is quite reasonable; on the other hand, the quantity absorbed is small, and possibly insufficient to protect the timber. In the case of 6 lbs. being taken up per cubic foot the price works out to R0-15-4 for a B. G. sleeper, a somewhat high figure, while when the absorption is 10 lbs. per cubic foot, a by no means excessive amount, the price of treatment amounts to R1-8-7, a prohibitive figure.

PAST RECORDS OF CREOSOTED SLEEPERS USED IN EUROPE AND INDIA.

Many records are available as to the durability of Creosoted sleepers in Europe. In the "Revue Generale des Chemins de Fer" of the Eastern Railway Company of France, it is stated that Creosoted oak sleepers last 15 years, and during that period 15 per cent. of them had to be replaced. In another report from Germany, quoted by Dr. Warth, of 67,678 oak sleepers treated with Creosote, 0·78 per cent. had to be removed after 10 years and 8·60 per cent. after 13 years, while from reports of the behaviour of untreated oak on eight different German lines, it is stated that from 6·71 per cent. to 80 per cent. had to be removed within 10 years.

Turning now to the results on Indian Railways, the latest report on the subject is from the Secretary of the Railway Board to the Inspector General of Forests, dated 28th February 1910, in which he writes as follows:—

> "Creosote pine imported from England continues to be used for some years by the Railways having access to the Western ports of India. Thus on the North Western Railway some creosoted pine sleepers were laid on the Kotri-Rohri section in 1897. These sleepers were imported Baltic pine. It is believed that all sleepers have, since 1897, been replaced by sleepers of other varieties."

> "A large number of Creosoted pine sleepers were also laid on the Southern Punjab Railway previous to the year 1094 and were estimated to last from 7 to 12 years."

> "The use of these imported Creosoted pine sleepers has been discouraged by the Consulting Engineer to the India Office, and no sleepers of this kind have been used of recent years on State Railways. Information regarding other Railways is very scanty, but it is known that in former years the Bombay, Baroda and Central India Railway imported considerable numbers of Creosoted pine sleepers; such sleepers were also used by the Bhavnagar-Gondal-Junagad-Porbandar Railway and to a limited extent by the Great Indian Peninsula Railway."

Dr. Warth in his report cites certain instances of the durability of Creosoted imported pine sleepers. He quotes one case in Madras where 30 per cent. failed within 12 months, on the other hand others lasted 7 and in some cases 9 years. Mr. Sibley, Chief Engineer, East Indian Railway, writing in 1870 stated that imported Creosoted sleepers gave entire satisfaction, and cites a case where the sleepers lasted 13 years.

Turning to the report of the International Railway Congress of 1902 on the causes of the deterioration of wooden sleepers, Appendix F., India, we find that the Bombay, Baroda and Central Indian Railway give the life of Creosoted pine as 6 to 8 years, while the Nizam's Railway puts their life at 10 years.

Summary.

As has already been pointed out, the durability of Creosoted timber is not only dependent on the species but very largely on the way the impregnation is carried out, as also on the quality of the Creosote employed.

As far as India is concerned, the difficulty to be overcome in introducing the Creosoting process appears to be the cost of the Creosote and until the product is prepared from Indian Coal-tar the prospects of working it on an economic basis seem to be limited. The question whether the hardwoods produced by our Indian forests are capable of absorbing sufficient quantities of any antiseptic, in order to render them serviceable for railway slepeers, is question of general importance which will be discussed in Chapter IV

Lastly, it is worthwhile recording the opinion of Hauptmann Malenković as to the possibility of introducing the Creosoting process into

India. This expert, who was good enough to submit a report on the subject of the possibility of Creosoting in India, writes as follows:—

> "The comparatively low boiling points of the tar acids is a factor of importance in warm climates. It appears to me that Creosoting which even in Europe is expensive, would be more so with you, and further as Creosote would certainly be quickly rendered volatile in tropical countries, one is led to believe that it would be unsuitable to your conditions."

(2) THE HASKINIZING OR VULCANIZING PROCESS.

BASIS OF HASKINIZING PROCESS.

The process of Vulcanizing wood, as invented by Colonel Haskin differs *in toto* from all other processes, for instead of injecting an antiseptic solution into the timber he makes use of the substances already in the timber, and under considerable pressure and at a high temperature produces sterilisation of the wood-fibre, wood-cells and wood-vessels.

The principles on which Haskin evolved his process depended on the fact that albuminous food was necessary to the life of fungi and insects. If by any process these albumens can be so altered in constitution that they are rendered useless to these destroying agencies, the chances of deterioration in the timber are very considerably reduced. Now albumens coagulate at a temperature varying from 71°—94°C, so that by heating timber and especially green timber, the albumens form a coating on the cell-walls of the wood. They also under heat and pressure form new substances. Mr. Chandler, of the School of Mines, Columbia College, New York, writes that he examined timber which had been treated by the Haskin Process, as well as untreated timber of the same species. He states that the treated timber had undergone a radical change by being subjected to the action of heat, and that 11·91 per cent. of new substances had come into existence. Of these, 0·36 per cent. were neutral oils and turpines and 10·78 per cent. consisted of resinous acids and other bodies, a very considerable proportion of which was made up of antiseptic and preservative substances.

The second factor introduced by Haskin in his process was to subject the timber to pressure. The basis of this idea was founded on the fact that lignification of the heartwood of a tree is produced under great

pressure, his idea being that this would take place in unseasoned timber provided it was subjected to such pressure.

The process is therefore to subject the timber to dry heat and high pressure, so as to coagulate the albuminous substances in the wood and change their chemical composition, thus to hermetically close each cell and at the same time render them unsuitable nutriment for fungi and insects, and by pressure to lignify the tissue.

NECESSARY PLANT REQUIRED.

So as to effectually bring about these chemical and mechanical changes it is necessary that the timber be in a green state when treated. The plant consists of one or more large iron cylinders of considerable strength sufficient to withstand the pressure necessary to lignify the timber. These are fitted with strong air-tight doors and running into them is a system of tram lines on which move the loaded trollies. A powerful air-compressing engine is required, as also an air-circulating engine, connected to the cylinders.

PROCESS OF VULCANIZING.

After the cylinders have been charged, a jet of steam is turned on to expel any surface moisture from the timber, which on collecting at the bottom of the retorts is drawn off by means of cocks. The air-compressing engine is employed to compress the air to a pressure of 200 lbs. per square inch, the heat generated by pressure being reduced by a spray of cold water. The moist compressed air is then dried and heated to between 94°C. and 149°C. and forced through the cylinders by the air-circulating engine. The hot dry compressed air is not allowed to stay in the Vulcanizing chambers but is made to circulate by allowing it to scape at one end in the same quantity as is forced in at the other, any drop in the pressure being compensated by the compression pumps. The process lasts from 6 to 10 hours according to the size of the timber to be treated.

COST OF PLANT AND TREATMENT.

The Secretary of the Haskin Wood Vulcanizing Co., Ltd., writing to the Consulting Engineer of Railways, Madras, states that the cost of an

installation to treat 450 standard size sleepers per day would be about £12,000 *f.o.b.* Liverpool.

The charge made for vulcanizing timber is $2\frac{1}{2}d.$ to $4d.$ per cubic foot, according to the hardness of the wood. These are English rates. Dr. Gibson, in his very interesting note on the subject which appeared in 1898, puts up an estimate for a plant costing R1,20,000, including sheds, etc. His estimate of working runs as follows :—

		Per annum. R a. p.
Depreciation at 10 per cent. on R 1,20,000 .		12,000 0 0
1 Engineer @	R350 per mensem.	
1 Machine-man @	" 100 " "	
1 Stoker @	" 30 " "	
1 Boiler clearer @	" 30 " "	
4 Coolies @ R12·8	" 50 " "	
	560	
Sundries . .	40	
	600	7,200 0 0
Annual repairs		800 0 0
	TOTAL .	20,000 0 0

He then goes on to state that such a plant could treat 1,60,000 sleepers per annum, which works out to 2 annas per sleeper. To this cost would have to be added Royalty charges, but it is understood that these would not be heavy were a plant to be erected in India.

INDIAN RECORDS OF HASKINIZED TIMBER.

The records of Haskinized sleepers laid down in India are meagre. The results of one experiment which was made by the Bombay, Baroda and Central India Railway are to hand. The Company laid down 5,000 treated sleepers chiefly in the Bombay and Broach Divisions. The sleepers in the Broach section fared badly, for within two years out of 500 sleepers 345 were badly attacked by white-ants, a fact which is attributed to the Broach Division being notoriously bad for white-ants. Those in the Bombay Division lasted better.

The Government of Burma reported in April 1901 that certain scantlings vulcanized by the Haskin process had been fixed in the ground at Rangoon for observation. Twenty-two species of timber were treated and laid down together with similar pieces of untreated timber. The results showed that after about one year practically all the treated scantlings, which numbered 24 in all were slightly cracked, that two had been attacked by white-ants and that the remainder were sound. The untreated scantlings numbered 56 in all. When examined about a year after being placed in an open line, all were found to be more or less cracked, while 2 were attacked by white-ants, 6 were pitted by white-ants and also decaying, and 3 showed signs of decaying without being attacked by white-ants. The results of this experiment prove little or nothing nor does the experiment appear to have been carried further. The Vulcanizing Company have many certificates to prove the value of the process, including one from America which states that slepeers under heavy conditions of wear and exposure have been experimented on with satisfactory results.

A report from the Chief Engineer, Great Western Railway, London, on an experiment made with 400 Haskinized sleepers is not altogether satisfactory. He states that it did not appear to stop the tendency to the development of fungi, and that it further appeared to have the effect of causing the white wood in the sleepers to perish at an unreasonably early period of its existence.

Summary.

The principles that underlie the system are sound enough, though the results so far obtained in India are not altogether encouraging. On the other hand, no very satisfactory experiments have as yet been carried out in this country, so that to condemn the system for India would be premature. It appears that if by the process it is possible to convert the albumens and especially such substances as the oleo-resins present in Dipterocarps and other species into antiseptics, the results might be quite satisfactory. Nothing but actual experiments carried out on proper lines can prove the value of this process for India. To arrive at any definite conclusions only those species which contain large quantities of albuminous substances or in which much resin or oleo-resin is present should as a commencement be tested, otherwise the fundamental principles on which the whole process is based will not be given effect to, and the process will not receive a fair trial.

Definite proposals as to further experiments with this process are made in Chapter IV.

(3) THE BOUCHERIE PROCESS.

PROCESS.

The Boucherie process consists in forcing a solution of sulphate of copper into green logs under pneumatic pressure, thus driving out the sap and replacing it by a solution of this salt. The timber after being processed in this way is ready for conversion.

INDIAN RECORDS.

This process which attracted a good deal of attention at one time, especially in France, was given a trial in India in 1865-66, when a plant was erected at Palghat on the Madras Railway. The woods experimented on were of 44 different species. The engineers reported unfavourably on the treated sleepers, in that they considered that the strength and durability of the timber were not increased by this process. The following figures show the result of these experiments, as given by Dr. Warth. The sleepers were laid down in February 1865 and examined in October 1866 :—

Sleepers in good condition .	7,143	68·0	per cent.
„ slightly split . .	2,802	26·7	„ „
„ badly „ . .	356	3·4	„ „
„ attacked by insects	184	1·8	„ „
„ rotten . . .	6	0·1	„ „
TOTAL .	10,491	100	per cent.

The species of timber which had been most injured were in order *Dillenia pentagyna, Terminalia Chebula, Stereospermum chelonoides, Terminalia belerica* and *Odina Wodier,* not one of which species appears in the list given in Chapter I, pages 11 and 12, as even possible timber for sleepers.

SUMMARY.

The experiments carried out in Madras with the Boucherie process did not prove successful ; on the other hand, the majority of the species tested did not in all respects fulfil the conditions necessary for sleeper timbers, leaving out of the question their durability, so that the

experiment cannot be considered as conclusive. On the other hand, sulphate of copper has in itself many drawbacks, the most important of which is that it is very liable to be washed out of the timber. For this reason the tendency both in Europe and America has been to discontinue its use, and this after prolonged experience as to the value of this salt as a preservative for timber.

With reference to the process itself it has the disadvantage that only green wood or wood which has been kept fresh in water can be used and that a considerable loss is caused by having to treat those portions of the log which on conversion have to be discarded as off-cuts and butt-ends.

(4) THE BURNETTIZING PROCESS.

Process.

The process by which chloride of zinc is injected into converted timber was started by Sir William Burnett and the process now bears the inventor's name. It consists in subjecting the timber to a partial vacuum and then immersing it in the solution varying in strength from 1 in 50 to 1 in 100, by measure, according to the quality of the timber. It was observed in Germany that a 3 per cent. solution was generally too strong, in that it injured the timber by its action on the iron fastenings. It was found that on the Brunswick lines, where a solution of 1 part in 30 of the chloride of zinc of commerce was used, that the sleeper-woods, after 5 years, showed discolouration and softness round the spike-holes causing the fastenings to become loose. Dr. Warth states that after the ill-effects caused by using a solution as strong as 1 in 30 had become apparent the strength was reduced to 1 in 60 and contained 0·66 per cent. of metallic zinc by weight, or 2·64 per cent. of chloride of zinc of commerce. In the experiments carried out by H. B. Eastman of the American Forest Service, a 6 per cent. solution was taken, the Open Tank method being probably employed.

The Use of Chloride of Zinc as an Antiseptic.

As was explained in Chapter I, page 8, the process has certain disadvantages such as the corrosive action of the salt on iron fastenings, besides which it is a highly hygroscopic substance. To overcome these drawbacks attempts have been made to use chloride of zinc together

with the heavier oils of Creosote and also mixed with sodium-fluoride. Even unmixed its action as a timber preservative is undeniably good and though not now used pure to the extent it was formerly, it still finds a place as one of the foremost salt antiseptics both in Europe and America. Mr. Sherfesee of the United States Forest Department states that—"In the United States the tendency in wood preservation is to modify the processes rather than to change the preservatives. At present, Creosote and zinc chloride pure or in mixture, are the only preservatives which are in general use." The Hauptmann Malenković does not favour zinc-chloride alone but recommends zinc-chloride mixed with equal proportions of sodium-fluoride, either injected under pressure or employed in the Open Tank method. In the former case the period of treatment is of short duration, while in the latter case immersion for 8 days is necessary in a more concentrated solution of the mixture.

From what has been said above it will be seen that chloride of zinc has still many supporters, who either advocate its use pure or when mixed with other substances. Another factor in favour of this process is that the salt has been in use for many years as an antiseptic and consequently has been given extensive trials over long periods of time and still remains in favour.

COST OF IMPREGNATION WITH CHLORIDE OF ZINC.

The cost of this process must depend entirely on the strength of the solution used and the amount of absorption by various classes of timber and further on to the method of treatment adopted, be it by injection or by immersion only. The price of chloride of zinc of commerce is R20 per cwt. in Calcutta (solid), so that with a solution of 1 in 50, and taking the absorption as 3 lbs., 6 lbs. and 10 lbs. per cubic foot respectively, according to the density of the timber to be treated and the cost of labour, etc., at R0-1-6 per sleeper, the cost of treating a B. G. sleeper according to the amount absorbed, would be R0-2-0, R0-2-8 and R0-3-5; in other words, this is an extremely cheap method of treating timber.

Dr. Warth, in his report, puts the cost of impregnating oak at 0·2*d.* and of beech at 0·4*d.* per cubic foot; which for treating a B. G. sleeper of oak works out at 0·66*d.* and of beech at 1·32*d.*, or adding 1·5*d.* to each as cost of processing, the cost of treating oak sleepers comes to 2·16*d.* and of beech sleepers to 2·82*d.*—prices very similar to those worked out for India.

INDIAN AND EUROPEAN RECORDS.

Dr. Warth gives records of results obtained with impregnated chloride of zinc sleepers on German lines, where the species were oak, Scotch fir, and beech. On a line in Hanover 168,690 treated oak sleepers and 81,002 treated beech were laid of which 2·20 per cent. and 4·90 per cent. respectively failed after 10 years; in another case, out of 78,385 treated Scotch fir sleepers laid down on the Brunswick line, 1·93 per cent. failed after the same period.

In 1864-65 a Burnettizing plant was erected at Kotri, on the Indus, costing R40,047, including buildings, etc. This plant appears to have been worked on the Open Tank method. The process consisted in boiling the sleepers for 6 or 7 hours and then allowing them to remain in the tank for 48 hours, the liquid being heated by a system of steam pipes. The result is reported to have been most unsatisfactory. Dr. Warth most justly remarks that it is difficult to understand how R40,000 were expended on so simple a business. The cost of treating each sleeper is given as R1-1-0, an extremely high price. What strength of liquor was employed is not stated, nor is any definite mention made as to the species of timber employed.

Another example is given by Dr. Warth of sleepers impregnated with chloride of zinc in 1869 and laid in the Sind, Punjab and Delhi lines. The species chosen for the experiment were Deodar and Chir (***Pinus longifolia***) some being treated by pneumatic injection and others by the Open Tank method. In the latter case the process consisted in soaking the Deodar and Chir sleepers for 4 hours in a solution heated to 77°C. These treated Chir and Deodar sleepers were laid down on the Delhi section, while untreated Deodar were laid down at the same time on the Punjab section. In the former case the treated Chir and Deodar sleepers were packed in inferior ballast, while the untreated Deodar sleepers were laid in good ballast. The results after four years were that 6 per cent. of the treated sleepers were faulty, while only 1½ per cent. of the untreated sleepers were reported to be unserviceable after 8 years. Obviously the comparison is unsatisfactory and proves nothing, for without doubt the bad ballast accounted for the rapid decay of the treated sleepers. Even without treatment Deodar has a much longer life than 4 years if properly packed, while it is quite possible that had the untreated Deodar sleepers been laid in the bad ballast they might have shown even a higher rate of decay than did the treated sleepers.

SUMMARY.

Unfortunately the experiments formerly carried out in India with the Burnett process are anything but conclusive. As has already been stated the value of corrosive sublimate as an antiseptic is fully recognised in Europe and America and that after having been in use for many years in those continents.

There is much to be said for the salt, especially its cheapness and the possibility of its being employed in conjunction with other more expensive antiseptics. It is a cheap process as compared, for instance, with Creosoting; further the American records tend to show that it can be employed with efficiency in the Open Tank method. In spite of adverse records obtained up to the present in India, the process or a modification of the process in conjunction with other antiseptics is certainly worthy of further attention. Definite recommendations as to future experiments to be carried out with this salt are given in Chapter IV.

(5) GARDNERIZING TIMBER.

PROCESS.

The process as described is divided into five stages, of which four are of an alternate nature. The first consists in seasoning the timber by chemically dissolving the sap. This appears to be done by steaming and then drying the wood and again steaming with a chemical, the composition of which is a secret; in other words, the timber is subjected to artificial seasoning. The second process consists in permeating the empty pores of the wood, under atmospheric pressure with a strong solution of borax. The third process is to render the timber non-inflammable; how this is done is not stated.

The fourth and fifth processes are either to treat the timber by immersion in bi-chloride of mercury (corrosive sublimate) or in Creosote.

The value of the system is said to lie in the chemical seasoning; it is, however, open to doubt whether the chemical itself or the artificial seasoning and after treatment with one or other of the well-known antiseptics, are the factors that constitute the value of the system as claimed by the inventor and Company, but it is highly probable that the seasoning and corrosive sublimate or Creosote has much to do with any merit there may be in the process.

No records appear to be available as to the behaviour of gardnerized wood in India, nor do any trials appear to have been made in this direction. Dr. Warth, in mentioning the process, seems to have had little reliable information on the subject, while the only further description available is one published in the *Indian Forester* of 1889, page 479, and even this is extremely vague.

(6) RÜPING PROCESS.

Theory on which the Process is based.

This is a new process, not that new antiseptics are used, for any of the recognised antiseptic solutions can be employed with a Rüping plant. The aim of the process is to reduce the quantity of any solution necessary for effective protection of the timber and so reduce the cost of impregnation. The process is based on the assumption that it is necessary only to protect the cell-walls of the wood and that it is not necessary to fill the cellular spaces in order to render timber proof against insects and fungi.

In the usual Creosoting process the seasoned timber is first subjected to a vacuum in order to remove the air and any remaining moisture from the timber after which Creosote is forced in to fill up the air-exhausted cavities and also to soak into the tissue.

The Process.

The reverse is the case in the Rüping process. Instead of a vacuum being formed, the seasoned timber is subjected to a pressure of 5 atmospheres; in other words, air is forced into the cellular spaces, instead of being drawn out of them. The antiseptic solution is then forced into the cylinder at a slightly greater pressure than 5 atmospheres, air being at the same time allowed to escape from the cylinder, but not in sufficient quantities to reduce the pressure below 5 atmospheres. On the timber in the cylinder being covered with the antiseptic solution the pressure is raised to about 15 atmospheres so as to force the fluid into the timber. The inventor and Company explain the fact that the air is neither forced out of the timber nor forced to form an air cushion in the centre of the beam, by the fact that the capillarity of the wood and the pressure in the cells force the fluid to keep to the cell-walls and thus instead of the

cell being filled with the antiseptic solution, only those portions of the timber are impregnated which are liable to decay, namely, the tissue of the wood.

It is claimed that the compressed air in the cells, on the pressure being taken off, drives any surplus fluid out of the timber, only leaving the amount required to saturate and fill the cell-walls. It is also stated that the oozing out of the superfluous solution can be further increased by forming a vacuum in the cylinder before the treated timber is removed.

Amount of Absorption and Cost.

By this process the absorption can be reduced to 40 kilos. per cubic metre or 2·2 lbs. per cubic foot as compared with anything between 5 to 20 lbs. per cubic foot absorbed when timber is treated by the common Creosoting method, and still the saturation of the tissue itself is said to be complete. Taking the absorption at 2·2 lbs. per cubic foot as stated above and the cost of processing at 1*a.* 6*p.* per B. G. sleeper, the cost of treating a sleeper works out at 6*a.* 2*p.*

Summary.

It is too early to predict what will be the ultimate effect on the preservation of timber by this process. The system has much in its favour, in that it is cheaper than the old Creosoting process; on the other hand, only time can prove if the timber so treated will be lasting or not. It appears to have this advantage, when considering our Indian hardwoods, that the pressure has necessarily to be high so as to force the solution into the timber, a condition that is very likely in any case to be necessary with such species as *Terminalia tomentosa, Dipterocarpus tuberculatus* or *Lagerstrœmia tomentosa,* all of which yield fairly hard-woods.

(7) CRÉSOL-CALCIUM PROCESS.

Process and Theory.

A recent process has been brought out by Mr. Felix Friedemann and Mr. Gustaf von Heidenstam in which they mix Crésol and milk of lime together, and impregnate the timber by any of the usual pneumatic methods.

The theory of this process is based on the assumption that only about 6 oz. of Creosote are necessary to protect a sleeper of 3 cubic feet, but

that owing to the difficulty of distributing the fluid evenly very much greater quantities have to be utilized. Now Phenol or carbolic acid dissolved in alcohol has but a slight antiseptic action though when dissolved in water its action is improved. Impregnation with Tar acids alone is not possible, nor can they be used in water solutions, being too volatile, not to mention expensive. The inventors therefore considered it necessary to try and bind the tar-acids by transforming them into salts soluble in water, but still not volatile. They claim to have done this by preparing a mixture of Crésol and milk of lime, the solution being composed of 15 grs. of burnt lime (90 per cent. to 95 per cent.) 46 cc. of Crésol containing at least 95 per cent. of tar-acids, and 500 cc. of water.

COST.

The Company work out the cost of treating a sleeper of 3 cubic feet in various countries as follows :—

Country.	Old method using 3 gallons of Creosote.			Latest method using 1 to 2 gallons of Creosote.			Crésol-Calcium salt 1·48 lbs.		
	£	s.	d.	£	s.	d.	£	s.	d.
England	0	0	9	0	0	3·6	0	0	1·40
Sweden	0	1	0	0	0	4·8	0	0	1·52
India	0	1	6	0	0	7·2	0	0	1·82

SUMMARY.

The process is based on the assumption that certain tar-acids are efficacious in the preservation of timber. It is accepted that these acids are beneficial, but they are also volatile, nor is it due so much to these tar-acids (not Phenols) that timber is rendered immune to decay as to the heavy oils of Creosote, with high boiling points, so that Crésol-Calcium for Indian work may not prove satisfactory, unless it can be shown that the boiling point of the compound Crésol-Calcium is considerably higher than that of Crésol alone.

CHAPTER III.

The Open Tank or Brush Method of Treating Timber.

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The Open Tank or Brush Method of Treating Timber.

(1) DISCUSSION AND DESCRIPTION OF THE PROCESS.

GENERAL.

The ever-increasing demand, together with the limited supply of first class timber, have gradually and steadily raised its price in most parts of the civilized world, until the high rates have prohibited its use for many purposes. Various proposals have from time to time been put forward to meet this difficulty in order to reduce the high price in the timber market, amongst which may be mentioned projects formulated as long ago as the first half of last century which aimed at prolonging the life of the timber by treating it with antiseptic solutions and thus, in a measure, checking the ever-increasing demand.

The first development in this direction consisted in the treatment of timber by pneumatic or hydrostatic injection, processes which require large and costly plants, generally of a stationary nature. As the forests retreated before the ever-advancing needs of agriculture and manufacturing industries and became split up into many blocks, the lead over which it became necessary to carry timber to the central markets increased, while the cost of moving the timber to these central places, at which large impregnating plants could be worked, became prohibitive

Again, as the value of the antiseptic treatment of timber became more fully recognised by landholders, firms and companies who often had occasion to treat small quantities of timber only, but the scope of whose work was not sufficient to justify the erection of an expensive plant, it was found necessary to devise cheap and more ready methods to meet their requirements.

Though the Open Tank method was in vogue early in the middle of last century, it was not until the seventies that much attention was paid to it, though the process of immersion of timber in corrosive sublimate no doubt dates from an earlier period. Since then much progress has been made in this direction and many patent antiseptic solutions, used in the Open Tank method, have appeared on the market.

DESCRIPTION OF THE PROCESS AND PLANT REQUIRED.

The Open Tank process consists in either immersing timber for a varying period of time in a hot solution of an antiseptic fluid, or of heating the timber in a hot bath and then quickly transferring it to a cold bath containing the preservative, or again of treating the timber in a hot antiseptic solution and allowing it to remain in the bath while the fluid cools down. The necessary apparatus consists of a tank, capable of withstanding heat and fitted either with coils of pipes for heating the solution, or capable of being placed over an open hearth. Such a plant is not of an expensive nature and is at the same time easily moveable, therefore it possesses great advantages over the large and costly apparatus necessary for hydrostatic or pneumatic impregnation.

METHOD OF TREATMENT.

The treatment, as now carried out, consists in the immersion of the timber for a period varying from 15 minutes to 24 hours and more, in a solution heated to a temperature of 77° C. and over. The temperature and period of immersion vary according to the density and anatomical structure of the wood; as an example, a piece of Pine or *Boswellia serrata* of 2″ × 2″ × 18″ becomes saturated throughout by an antiseptic such as Carbolineum oil, after an immersion of 15 minutes, at a temperature of 77° C., while the solution only penetrates to the depth of one-eighth of an inch along the fibre and one-sixteenth of an inch across the fibre in the case of closer grained woods, such as the Dipterocarps, indicating that a more drastic treatment is required.

THEORY ON WHICH THE PROCESS IS BASED.

The theory underlying the Open Tank process is based on the fact that a vacuum exists in seasoned timber and that it is further increased by immersion in a hot bath, in that the air on being heated expands and is expelled from the wood. Now, after the timber has been immersed in a hot solution if allowed to stay in the liquid as it cools down, on the temperature dropping the vacuum comes into play and as the wood is immersed, instead of the air again filling the cellular spaces, its place is taken by the antiseptic fluid.

In support of the above theory it is only necessary to watch the process of treating such porous woods as *Bombax malabaricum* and *Odina Wodier*, in which as the liquid is heated masses of air bubbles appear on its surface, showing that the air in the timber is being expelled, and after completing the process to cut open the treated specimen and examine the amount of absorption.

Capillary attraction without doubt helps the absorption of the liquid, as a proof of which it may be said that similar results are obtained to those described above when immersion takes place in a cold bath; on the other hand, the quantity of air expelled is less than when the piece is treated in a hot solution, and the amount of fluid taken up proportionately reduced, and further the absorption is even then not wholly due to capillary attraction, but to the vacuum already existing in the seasoned timber.

At one time it was thought that the vacuum was produced by the expulsion of moisture out of the timber when heated, but this is not so, for were that theory correct, green timber which had been previously soaked in water on being heated would absorb more of the preservative than seasoned wood, which is found not to be the case in practice.

As a further proof of the vacuum theory, two pieces of *Dipterocarpus tuberculatus*, the Burman "In" wood, of equal size (12″ × 3″ × 3″) were treated with *Avenarius Carbolineum* oil. One piece was immersed in the solution heated to 200° F. for 15 minutes and allowed to remain for 45 minutes, in the bath while it cooled down, the immersion period being in all one hour. The other piece was treated for one hour in the solution heated to just below boiling point, the temperature being maintained throughout. Thus, in the first case, the suction caused by the vacuum came into play while the fluid cooled down, in the latter though the vacuum was formed by heating the timber it was not given the opportunity of acting on the piece in the same way as in the first case. The results were interesting, in the first case the quantity of oil absorbed was slightly more than double that in the latter case.

EFFICIENCY AND VALUE OF THE PROCESS.

The efficiency and value of the process must depend on (i) the antiseptic employed, (ii) the intensity of treatment, (iii) the adaptability of the various Indian timbers to such a treatment, and (iv) the purpose for which the timber is intended and the locality in which it is placed.

As to the relative value of the various antiseptic solutions which can be used in the Open Tank method, they will be dealt with in detail hereafter.

INTENSITY OF TREATMENT.

By the intensity of treatment is meant the duration of the period of immersion of the timber, the temperature to which it is heated and the strength of the solution. As stated above, soft woods require a shorter period of immersion than hard woods.

The various companies in advertising their patent solutions state the time necessary for immersion and the temperature to which the solution should be raised, they having based their recommendations on experiments carried out with such soft species as beech and European conifers. From experiments carried out in the laboratory on Indian hard woods with some eight or ten patent solutions, after examination of the inside of the treated specimens, the conclusion arrived at was that in many instances the treatment to be of value, must be of considerably longer duration, a solution of greater strength being required, and that each different antiseptic calls for treatment according to its own merits and limitations.

Details of experiments will be given hereafter, it being sufficient to say in proof of the above assertion that such soft woods as *Boswellia serrata* and the Indian conifers can be effectively treated by immersion in a hot solution for 20 minutes to half an hour, harder timber such as "In" (*Dipterocarpus tuberculatus*) requires two hours, while immersion for a period of four to eight hours is probably excessive in their case; again a twenty-four hour immersion of very hard woods such as *Pterocarpus Macrocarpus* (Burman Padauk) appears insufficient.

The period of immersion must also be regulated by the depth of penetration necessary to preserve the timber. This can only be ascertained by experiments carried out in the field and extending over a considerable period of time. Probably the penetration into soft timber will have to be greater than in the case of hard woods. Provisionally it may be stated that in the case of soft woods a penetration of three inches on the sides and six inches at the ends will be sufficient to protect large pieces of timber, while in the case of hard woods effective protection will be obtained by an absorption to half that depth.

ADAPTABILITY OF INDIAN SPECIES TO TREATMENT BY THE OPEN TANK METHOD.

The most important question is the probable effect of the Open Tank treatment on our harder Indian timbers. Many experiments have been carried out in this connection on a laboratory scale and others are to be made on a large scale by treating several thousands of sleepers of the harder Indian timbers with different antiseptics. In the laboratory tests carried out no difficulty was found in treating the soft timbers as they readily take up the solution in which they are immersed. The case of moderately hard woods which are of sufficient strength for the purpose of sleepers is more difficult. By prolonging the period of immersion they can be made to take up sufficient quantities of the antiseptic to protect the timber, but the difficulty lies in fixing the period, as over-cooking means excessive cost of treatment, and on the other hand, curtailing the period of immersion may result in insufficient protection. Only extensive experiments with each species will settle this point. As regards the very hard woods, it is as yet doubtful if treatment by this method is possible. The results of laboratory experiments on such species as Sal, Padauk and Dhaura or Bakli (*Anogeissus latifolia*) show that after immersion for 24 hours the solution has hardly penetrated one-sixteenth of an inch, probably an insufficient depth for their preservation; on the other hand, many of the very hard woods are sufficiently good timbers to require no treatment, or are so hard that the cost of conversion of the timber into sleepers is impracticable.

THE PURPOSE FOR WHICH THE TREATED TIMBER IS REQUIRED.

The last point on which general remarks are necessary, before dealing in detail with the various antiseptics, is the purpose for which the treated timber is required and the climatic conditions of the locality in which it is to be placed. Our primary consideration is with railway sleepers and to a less degree with such timbers as are used for telegraph poles and fencing posts, mining-props and in construction work. The timber required for sleepers amongst other qualities, should be strong and hard, a condition not altogether favourable for treatment by the Open Tank method, but one that can probably be overcome by careful manipulation. The case of telegraph poles and fencing posts, as also that of mining-props is different, strength is essential but

to a lesser degree; on the other hand, the conditions under which the timber is placed in the ground or in damp hot mining galleries are not so favourable as those in the case of a sleeper lying in clean ballast. The result of such variations in the climatic and atmospheric conditions will necessitate the use of stronger solution and entail deeper impregnation in the case of mining-props and the butt-ends of posts to be placed in the ground, than in the case of sleepers or such timber as is not liable to excessive and continued damp.

SUMMARY.

The results which may be obtained by treating timber according to the Open Tank method are likely to vary considerably according to the climatic influences to which the treated timber is exposed. The advantages of pneumatic injection, by which a timber is impregnated throughout are obvious, especially when the treated timber is placed in localities of heavy rainfall such as occurs in many parts of India. By immersion it is not always possible to obtain complete saturation, besides which to do so is often expensive and it remains to be seen if partial impregnation will answer our purpose, especially under the many adverse conditions in which such sleeper timber must naturally be placed, while the result must largely depend on the power of the antiseptic employed to withstand being washed out of the timber or evaporated by excessive heat.

(2) CHLORIDE OF MERCURY OR THE "KYANIZING" PROCESS.

CORROSIVE SUBLIMATE.

One of the earliest methods of treating timber was to subject it to a bath of chloride of mercury (corrosive sublimate) and without doubt the process was most beneficial, for Kyanizing timber, as the process is named after the inventor, is still employed by the State Telegraph Companies in Germany. The system would be more universally in favour at the present day, were it not for the fact that the salt is highly poisonous and at the same time expensive.

DESCRIPTION OF THE PROCESS.

The process is a simple one, the timber is immersed for 10 to 15 days in a weak solution of 1 in 100 to 1 in 150, the tanks into which the solution is run being generally made of wood as the sublimate corrodes iron.

EUROPEAN AND INDIAN RECORDS.

As stated above, the salt is used for impregnating telegraph poles in Germany and its action is undoubtedly beneficial, while its use for poisoning seeds, museum wood and botanical specimens is well known.

Dr. Warth states that it was used on the Baden and Rhein-Nahe Railways for impregnating sleepers as long ago as 1840, and that the results were most satisfactory, treated sleepers having a life of 20 years and upwards, but that afterwards the system of impregnating with chloride of zinc took its place, being a cheaper process.

Chloride of mercury has been experimented with in India by the Great Indian Peninsula Railway, but only with very inferior species and not with the better class of "auxiliary species" of timber. The results were fairly satisfactory, in that the sleepers were in good condition after four years; however, the high cost of treating the sleepers caused the experiment to be discontinued.

COST OF TREATING.

Dr. Warth states that corrosive sublimate is taken up by all woods alike at the rate of 0·066 lbs. of the salt per cubic foot. He further states that the cost of processing is estimated at 0·5*d.* per cubic foot and the cost of the salt at 2·5*d.* per cubic foot, and therefore 3*d.* per cubic foot for the whole process. This estimate is based on the assumption that the strength of the solution used is 0·66 per cent. of salt. It is not known on what grounds the statement is based that all timbers alike take up 0·066 lbs. per cubic foot, as it appears likely that the soft species would take up more than heavy and close-grained woods. Assuming that this is correct and that the present price of corrosive sublimate

in Calcutta is R2-4 per pound, and further that the solution used is 1 in 100, we get the following figures for treating a broad-gauge sleeper :—

Species.	Amount absorbed by a B. G. sleeper per cubic foot.	Cost of treating sleepers.	Cost of salt absorbed by a B. G. sleeper.	Total cost of impregnation.
		R a. p.	R a. p.	R a. p.
Hard timber .	3 lbs.	0 1 0	0 3 7	0 4 7
Moderately hard timber.	6 lbs.	0 1 0	0 7 2	0 8 2
Soft timber .	10 lbs.	0 1 0	0 11 11	0 12 11

SUMMARY.

The method of impregnating with corrosive sublimate is without doubt of value. In India, however, it is undesirable to use so poisonous a substance, besides which the process is somewhat expensive and therefore not to be recommended.

(3) SACCHARINE SOLUTION OR THE POWELLIZING PROCESS.

SACCHARINE SOLUTION.

The actual composition of the solution used in Powellizing timber is kept secret; it is said to be made up largely of sugar, with possibly a small percentage of arsenic added to it, and no doubt also other substances. The idea of treating timber with a saccharine solution is reported to have been evolved from the fact that the timber of which sugar-vats are made is practically ever-lasting, a not improbable fact.

Without doubt sugar is a preservative, and though not used for this purpose in connection with timber before the idea occurred to Mr. Powell to do so, it has been for many years used as a preservative in other industries.

DESCRIPTION OF THE PROCESS.

The process of Powellizing timber is not dissimilar to that of all other Open Tank methods, though the artificial drying process is in this case added to the business.

The timber to be treated is run into a tank of suitable size, the tank being fitted with a door on one side and the loaded trucks run into the chamber on a system of tram-lines. On the tank being filled with timber, the entrance is closed and the saccharine solution in a cold state run in, until the wood is completely immersed by the liquid. The solution is then gradually heated to boiling point by a system of heating pipes and maintained at that temperature for a few hours, the period of immersion at this temperature varying according to the dimensions and class of the timber to be impregnated. The solution is then allowed to cool down, after which the liquid is run off and the wood removed to the drying chambers. It is then subjected to a process of artificial drying, which is effected by gradually raising the temperature in the drying chamber until sufficient desiccation has taken place, after which the timber is removed and said to be ready for use. The temperature to which the air is at first raised is stated by the Company to be 130°—140° F. and the humidity 85—90 per cent.; the temperature is gradually increased until it reaches 165°—170° F. with a humidity of 35 per cent. towards the end of the drying process. The time required to dry the wood depends on the class and dimensions of the timber to be treated; as an instance, it may be stated that a 1 inch piece takes three-fourths of a day.

THEORY ON WHICH THE PROCESS IS BASED.

The process, as above described, resembles many of the Open Tank methods now in use with other antiseptic solutions. The theory, which has been expounded on page 38, as to a vacuum existing in seasoned wood does not hold good for this process as the timber to be treated may be green. On the other hand, the theory that a vacuum is formed in the cellular spaces of the timber by the expansion of air on heating, does apply to this process. The necessary conditions of an Open Tank treatment are further fulfilled by keeping the timber to be treated in the solution until it has cooled down, thus allowing it time to

absorb the preservative with the help of the suction caused by the vacuum. Professor Norman Rudolf, M.Sc., F.I.C., Chief of the Department of Applied Chemistry at the Indian Institute of Science, was employed by the Bombay Branch of the Powellizing Company, to study the process. He explains it as follows :—

"During the time that the wood is immersed in the hot saccharine solution, the air entangled in the cells of the wood escapes, the albuminous matters are coagulated and both the saccharine matter and the poisonous substances penetrate into the pores of the cells. In the desiccating chamber the excess of moisture is rapidly removed with the result that after being allowed to cool the wood is fit for immediate use, being well seasoned. A microscopical examination of thin sections of Powellized wood reveals the fact that its cells are swollen up, some being apparently filled with the saccharine matter in a non-crystalline form; the saccharine solution having actually become a part of the structure of the wood. It is to this filling up of the pores that the Powell process owes its great value as a preservative of rot and decay, as rotting is due to the penetration of the wood by fine fungoid growths which in the treated wood have not chance of entering into its fibre."

MERITS OF THE PROCESS AS CLAIMED BY THE COMPANY.

The Company claim that the timber treated by this process is rendered immune to the attack of fungi and white-ants, that it tends to reduce shrinking, expanding, warping or splitting after treatment, and further that the appearance of the wood is improved and that its strength is probably increased, while the wood remains odourless. It is also stated that by this treatment the timber becomes impregnated throughout with the antiseptic, a most important consideration.

Time alone can prove the most important of these claims; that the timber is odourless after treatment is certain, and also though in most cases its appearance remains unchanged, in some instances the grain is improved in appearance. As regards the strength of the treated as compared with that of the untreated timber, no criticism can be made, as the tests carried out in this direction make no mention of the percentage of moisture in the timber at the time of examination. A machine has been prepared for carrying out expansion and contraction tests, and it is hoped that definite results in this connection will in due time be available.

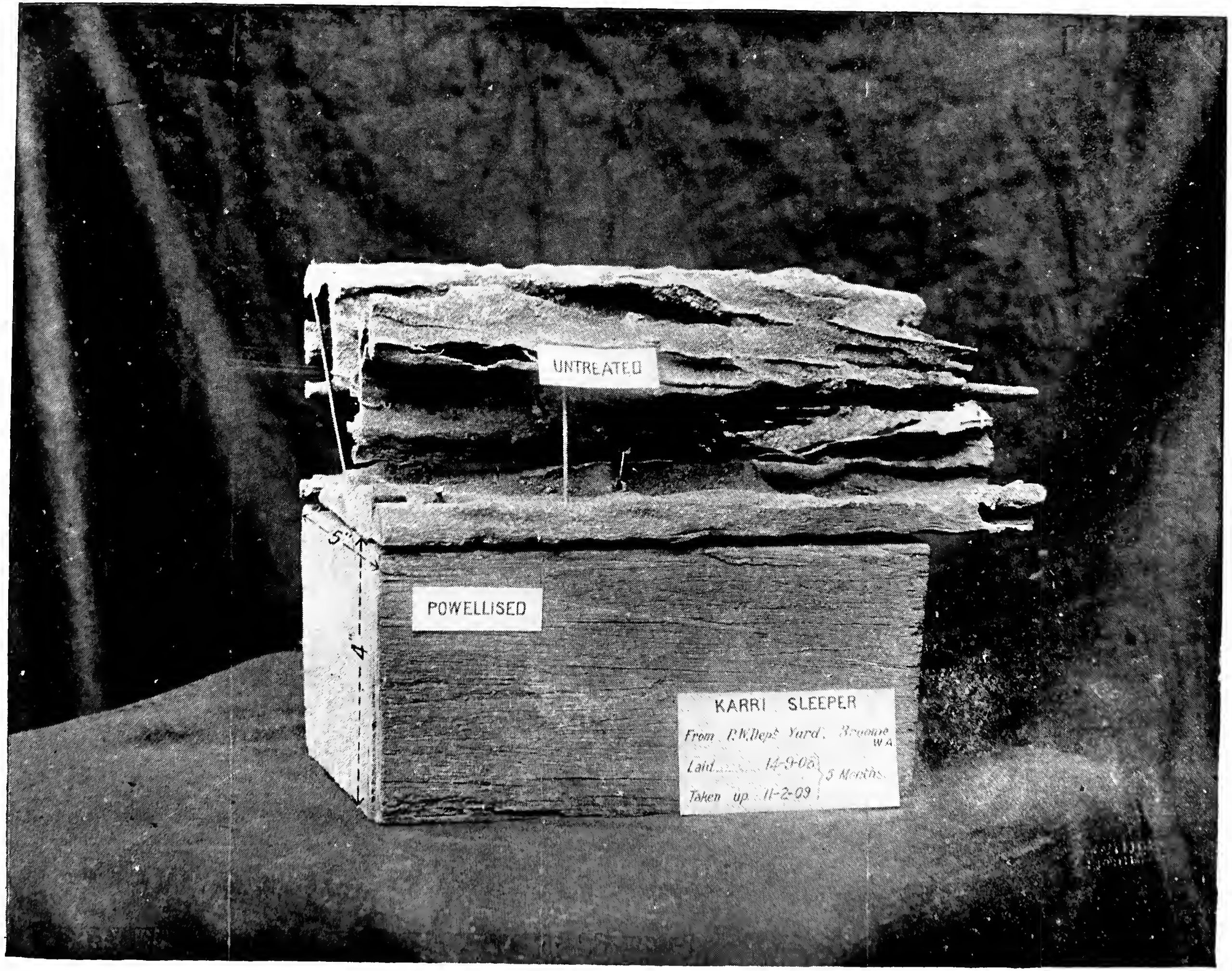


Photo-Mechl. Dept., Thomason College, Roorkee.

The question whether the timber is impregnated throughout by this process is a most important one. From records to hand it seems that it is so, especially in the case where moderate-sized scantlings have been treated. No doubt if large beams of hard-wood were treated, the duration of the period of boiling would have to be considerably longer than would be the case with pieces of small dimensions; probably this would result in the cost of the treatment becoming excessive.

PAST RESULTS OBTAINED IN TREATING TIMBER BY THE POWELL PROCESS.

Much attention has been paid in recent years to this process, both by Government officials and by the public in India, as also by interested companies and firms in other parts of the world.

The Powell Company in their various pamphlets give a number of records exhibiting the value of the process. Besides these records, which are of great value, much information is available from other sources, a *précis* of which is given below.

RECORDS OF TESTS CARRIED OUT IN AUSTRALIA.

The Chief Engineer, Western Australia Railways, sent the following letter, dated 30th May 1910, to the address of the Imperial Forest Economist, on the subject of Powellized sleepers for use on the Railways in that State:—

"Our experiments in respect of Powellizing have been principally in the treatment of Karri timbers for the prevention of dry rot. Some four years ago a number of processed Karri sleepers were placed in the line sandwiched in between sleepers badly affected with dry rot and have stood the test well, proving thoroughly resistant to the inroads of the fungus."

NOTE.—Plate I is an illustration from a photograph sent by the Chief Engineer, West Australian Railways, showing pieces of treated and untreated Karri, after having been laid down in the ground for five months.

"The Public Works Department also has carried out exhaustive tests with Powellized timbers in the North-West of this State (where white-ants are particularly numerous and voracious), to determine the efficacy of the treated timber in resisting the attacks of the termites, with generally satisfactory results."

"The value of the treatment having been fairly well established, the Government authorised the construction of a Powellizing plant, and one capable of processing on an average 9,000 ($7' \times 9'' \times 4\frac{1}{2}''$) sleepers per week has been erected at Banbury (a seaport south of Perth, which is the outlet for most of the export timber of the State), where it is intended to treat for Government use, particularly for Railway construction and maintenance purposes, such timbers as are susceptible to dry rot and termites. The plant was erected by and is under the control of the Railway Department, and we are now processing the timber required for construction of the Port Headland-Marble Bar Railway, a line of about 114 miles in length in the North-West (Tropics)."

"The plant has not been long in operation and so far the cost has come out at 7*d.* per sleeper, *plus* royalty to the Patentees."

In another letter by Mr. Bacon addressed to a gentleman in England, he states that in West Australia "the Commissioner of Railways has agreed that all timber used in the railway systems of the State shall be powellized." Further that "the Powell Company in New South Wales puts through something like one million feet of timber a month, used for Railway sleepers, wood-paving blocks, etc., and that in New Zealand much the same amount is treated monthly."

From the above records it will be seen that in Australia and New Zealand the process has been accepted by many of the Railway Companies and that the results up to date are very favourable.

Many other records are available from other parts of the world, notably from the Philippines, Malay States, Natal, and the Transvaal, all of which are satisfactory, though the experiments on which the reports are based are not so exhaustive as those carried out in Australia.

Indian Records.

A fair number of experiments have been carried out in India with powellized timber but none of them on a very extensive scale. The first set of experiments were carried out at the instigation of Mr. Ryan, Deputy Conservator of Forests, Bombay. These consisted in clamping together treated and untreated blocks of three varieties of timber. These were placed in ant-hills on the 5th April 1906, and examined on the 13th September 1906; one set was attacked by the ants, the treated pieces of the other two were untouched, while the untreated pieces were heavily attacked by white-ants.

A number of powellized sleepers of different species were laid down at the instigation of the Forest Department on the Pyinmana line in Burma together with untreated sleepers of the same species. The results of this experiment according to the last report are as follows:—

No.	Species.	TREATED SPECIES.			UNTREATED SPECIES.		
		No. laid down.	Date of laying in open line.	Condition on 1st October 1910.	No. laid down.	Date of laying in open line.	Condition on 1st October 1910.
1	*Dipterocarpus tuberculatus.*	10	March 1908	Sound.	10	15th April 1907.	One removed in July 1910, one failing, the rest sound.
2	*Dipterocarpus turbinatus.*	10	Do. .	Do.	10	Do. .	One removed in 1909, the rest sound.
3	*Albizzia odoratissima.*	10	Do. .	Do.	10	Do. .	One removed in July 1910, the rest sound.
4	*Albizzia procera* .	10	Do. .	Do.	10	30th July 1907.	One doubtful.
5	*Homalium tomentosum.*	10	Do. .	Do.	10	15th April 1907.	Eight removed in 1908-09, one in 1910, the last failing.
6	*Schleichera trijuga*	10	Do. .	Do.	10	Do. .	Seven removed in July 1910; three sound.
7	*Terminalia belerica*	10	Do. .	Do.	10	Do. .	All ten removed in 1909.
8	*Terminalia tomentosa.*	10	Do. .	Do.	10	Do. .	All in good order.
9	*Careya arborea* .	9	September 1907.	Do.	10 1	Do. . September 1907.	Ditto.
10	*Pinus Khasya* .	9	Do. .	One removed in 1909, the rest in order.	10 1	January 1907. September 1907.	Four removed in 1908 and six in 1909.

The above sleepers were again inspected by the writer of this Note in February 1911 and found to be in good order.

Another set of experiments has been in progress at the Forest Research Institute, Dehra Dun, since April 1909, where a considerable number of different species of powellized timbers have been received from Messrs. Killick, Nixon & Co., Agents to the Powell Company in Bombay, which were originally sent by Forest Officers to the Powellizing Company for treatment. On their receipt at the Institute they were all laid down in the ground together with untreated specimens of the same species. The greater majority of the specimens were placed upright in the ground, as it was thought that in this position, being half under ground and half exposed to climatic influences, they would be

placed under the most exposed condition possible. The results up to date are as follows:—

TREATED.				UNTREATED.		
Register Serial No.	Species.	Laid down on	Condition on	Register Serial No.	Laid down on	Condition on
2	Powtik, (scientific name not known.)	24th April 1909.	16th August 1910. Sound.	1	24th April 1909.	16th August 1910. Badly attacked by white-ants on under surface.
4	*Mangifera indica* .	Do. .	Do. .		Do. .	Attacked by white-ants and decay, taken up on 30th October 1909.
5	*Hardwickia pinnata* .	Do. .	Do. .	6	Do. .	Sound on 16th August 1909.
8	*Boswellia serrata* .	Do. .	Do. .	7	Do. .	Half eaten away by white-ants, and taken up on 6th September 1909.
9	*Adina cordifolia* . .	Do. .	Do. though slightly split.	10	Do. .	Slightly pitted by white-ants, 16th August 1910.
	Calophyllum Inophyllum.	Do. .	Sound .	12	Do. .	Sound on 16th August 1910.
14	*Sonnerata apetala* .	Do. .	Do. .	13	Do. .	Very slightly touched by white-ants, 16th August 1910.
16	*Excœcaria Agallocha* .	Do. .	Do. .	15	Do. .	Lower surface completely eaten away by white-ants, taken up on 16th August 1910.
17	*Pinus longifolia* . .	Do. .	Do. .	18	Do. .	White-ants were working over the surface of the specimen on the 30th October 1909, since then they appear to have left it.
20	*Pinus excelsa* . .	Do. .	Do. .	19	Do. .	Sound. White-ants worked over the surface of the specimen on the 30th October 1909 and have now left it.
21	*Picea Morinda* . .	Do. .	Do. .	22	Do .	Sound.
24	*Lagerstrœmia microcarpa.*	Do. .	Do. .	23	Do. .	Do.
26	*Cedrela Toona* . .	Do. .	Do. .	25	Do. .	Do.
27	*Terminalia bialata* .	Do. .	Do. .	28	Do. .	Do.
29	(Missing) . . .	...	...	...	...	......

Treated.				Untreated.		
Register Serial No.	Species.	Laid down on	Condition on	Register Serial No.	Laid down on	Condition on
30	*Artocarpus hirsuta* .	27th January 1909.	16th August 1910. Sound.	...	...	......
31	*Albizzia Lebbek* . .	Do. .	Do. .	...	...	......
32	(Species doubtful) .	...	...	...	...	......
33	*Myristica Irya* . .	Do. .	Do. .	...	...	......
34	*Alphonsea ventricosa* .	Do. .	Do. .	...	...	......
35	*Dipterocarpus turbinatus.*	Do. .	Do. .	...	...	......
36	*Mesua ferrea* . .	Do. .	Do. .	...	...	......
37	*Artocarpus Chaplasha* .	Do. .	Do. .	...	...	......
38	*Pterocarpus dalbergioides.*	Do. .	White-ants working over surface but not actually attacked the timber.	...	...	......
39	*Lagerstrœmia hypoleuca*	Do. .	Sound .	...	...	......
40	*Bombax insigne* . .	Do. .	Do. .	...	...	......
41	*Hopea odorata* . .	27th April 1909.	Do. .	...	...	......
42	*Terminalia paniculata* .	13th November 1909.	Do. .	43	13th November 1909.	Sound.
44	*Bombax malabaricum* .	Do. .	Do. .	45	Do. .	Completely eaten by white-ants and taken up on 15th May 1910.
46	*Careya arborea* . .	Do. .	Do. .	47	Do. .	Sound on 16th August 1910.
48	*Terminalia tomentosa* .	Do. .	Do. .	49	Do. .	Ditto.
50	*Cassia Fistula* . .	Do. .	Do. .	51	Do. .	Ditto.
2	*Anogeissus latifolia* .	Do. .	Do. .	53	Do. .	Somewhat pitted by white-ants at base, 16th August 1910.
54	*Lagerstrœmia lanceolata.*	Do. .	Do. .	55	Do. .	Sound, 16th August 1910.
56	*Xylia dolabriformis* (from Bombay).	Do. .	Do.	57	Do. .	White-ants working over surface on 9th July 1910, left it 16th August 1910.
58	*Phyllanthus Emblica* .	Do. .	Do. .	59	Do. .	Slightly attacked by white-ants, 16th August 1910.
60	*Grewia tiliæfolia* .	Do. .	Do. . slightly split.	61	Do. .	Ditto.

Treated.				Untreated.		
Register Serial No.	Species.	Laid down on	Condition on	Register Serial No.	Laid down on	Condition on
62	*Stephegyne parvifolia* .	13th November 1909.	16th August 1910. Sound.	63	13th Nov. 1909.	Slightly attacked by white-ants, small bracket fungus above ground, 16th August 1910.
64	*Lagerstrœmia parvifolia.*	Do. .	Do. .	65	Do. .	White-ants working at it, 16th August 1910.
66	*Gardenia turgida* .	Do. .	Do. .	67	Do. .	Sound.
68	*Calophyllum tomentosum*	Do. .	Do. .	69	Do. .	Pitted by white-ants.
70	*Tectona grandis* .	Do. .	Do. .	71	Do. .	Sound.
72	*Dipterocarpus tuberculatus.*	Do. .	Do. .	73	Do. .	Do.
74	*Xylia dolabriformis* . (from Burma)	Do. .	Do. .	75	Do. .	Do.
76	*Terminalia belerica* .	Do. .	Do. .	77	Do. .	Slightly attacked by white-ants. Bracket fungi on stem.
78	*Stereospermum Xylocarpum.*	Do. .	Do. .	79	Do. .	Sound.
80	*Casuarina equisetifolia*	Do. .	Do. .	81	Do. .	Whole of base eaten away by white-ants, taken up.
82	*Dillenia pentagyna* .	Do. .	Do. .	83	Do. .	Badly attacked by white-ants and taken up.
84	*Garuga pinnata* . .	Do. .	Badly attacked by white-ants and taken up.	85	Do. .	Ditto.
86	*Odina Wodier* . .	Do. .	Sound .	87	Do. .	Badly attacked by white-ants, also heavy growth of fungus present, taken up.
88	*Schrebera swietenioides*	Do.	Do. .	89	Do. .	Sound.
90	*Tabernæmontana Heyneana.*	Do. .	Do. .	91	Do. .	Slightly pitted by white-ants.
92	*Butea frondosa* . .	Do. .	Do. .	93	Do. .	Slightly attacked by white-ants, 16th August 1910.
94	*Polyalthia fragrans* .	Do. .	Do. .	95	Do. .	Heavily attacked by white-ants and taken up on 15th May 1910.

Treated.				Untreated.		
Register Serial No.	Species.	Laid down on	Condition on	Register Serial No.	Laid down on	Condition on
96	*Buchanania latifolia* .	13th Nov-1909.	16th Aug. 1910. Sound.	97	13th Nov. 1909.	Badly attacked by white-ants and taken up on 16th August 1910.
98	*Acacia Catechu* . .	Do.	Do. .	99	Do. .	Sound on 16th August 1910.
100	*Pongamia glabra* . .	26th Dec-1909.	Do. .	101	Do. .	Ditto.
102	*Vitex altissima* .	Do. .	Do. .	103	Do. .	Ditto.
104	*Bauhinia malabarica* .	Do. .	Do. .	105	Do. .	Ditto.

From the above table it will be seen that with the exception of one specimen (*Garuga pinnata*) all the treated specimens were sound on the date of inspection, while of the untreated specimens ten have been so badly attacked as to necessitate their removal, and several others are by no means doing well.

The above experiments are all on a laboratory scale; arrangements have been made to powellize 5,000 sleepers of five different species, which after treatment will be laid on open lines and kept under observation.

COST OF TREATMENT.

The cost in Bombay, as charged by the Company, for treating sleepers is 5 annas per cubic foot, which works out to R1-0-6 per B. G. sleeper. The Chief Engineer, Western Australia Railways, gives the price as 7*d.* per sleeper of 1·9 cubic foot or 3·68*d.* per cubic foot, *plus* royalty to the patentees. Mr. Ryan quotes the figure of £0-5-8 for treating 50 cubic feet in such localities where sugar is cheap exclusive of royalty charges. It should be mentioned here that the plant now in Bombay is more of the nature of an experimental plant, and that were the processing to be carried out on a large scale the cost of treating the timber would probably be reduced. Estimates as to cost of plant can be obtained from the Agents to the Company, Messrs. Killick, Nixon & Co., Bombay.

SUMMARY.

The Powellizing or Saccharine process is a comparatively new method of preserving timber. As compared with other Open Tank processes the

initial outlay for erecting the plant is heavy, while treatment at 5 annas per cubic foot is also higher than other similar processes. This is no doubt due to the cost of the sugar solution, the comparatively long period of immersion in the liquid at boiling point, and especially to the cost of the artificial method of drying the timber. Taking, as an example, the cost of converting and landing a B. G. Pine sleeper at Jagadhari station on the North-Western Railway from the Tons forests at R1-4-0, the price of the timber as 6 annas per cubic foot or R1-3-9 per B. G. sleeper, the cost of processing at R1-0-6, the total cost of a treated sleeper comes to R3-8-3, as against R4-0-0 for an untreated Deodar sleeper, whose life we know to be 12 years.

As regards the value of this process, the Australian experiments carried out over a period of 4 years go far to prove that it in a great measure fulfils the conditions claimed for it by the inventor, while the experiments made on railways in Burma with Indian species are also favourable. The laboratory experiments have not as yet had time to prove anything further, than that it renders immune the very soft timber of India to the attack of white-ants for at least one year.

Lastly, a point much in favour of this process is that green timber can be treated, obviating the necessity of resorting to the tedious process of naturally seasoning the logs.

(4) AVENARIUS CARBOLINEUM.

AVENARIUS CARBOLINEUM.

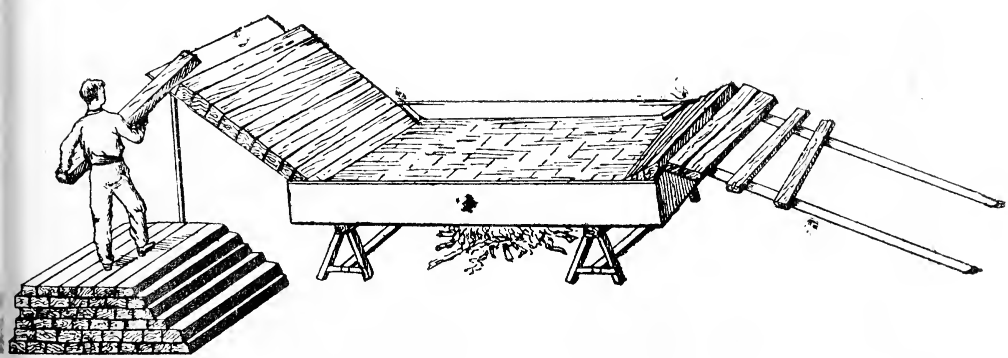
The group of oils obtained by the distillation of coal-tar and known on the market as Carbolineum oils, consist of those oils heavier than water which together with tar acids go to make up Creosote. The two grades best known on the market are *Avenarius Carbolineum,** an antiseptic solution which was first brought on the market some 30 years ago by Mr. Avenarius and *Carbolineum marque de Lion.* The former, according to an analysis, made by Dr. Filsinger of Dresden, and quoted by Monsieur Henry in his "Préservation des Bois" contains oils distilling at

* Agents for Bengal and Eastern Bengal and Assam, C. & A. Danby, 14, Radha Bazar Lane, Calcutta; and Agent for all India, G. Wense, Agra, United Provinces; cost R11 per 5 gallon drum, or, R1-12 per gallon; wholesale price, *c.i.f.*, Calcutta, Bombay and Karachi, R1-10 per gallon for orders of over 100 casks. One gallon weighs 11 lbs. 4 oz.

230°C. and over and has the high density of 1·128. Its viscosity at 17°C. as compared with water is 10, while it contains 10·6 per cent. per volume of oils distilling between 230°C. and 270°C., and 12·2 per cent. of oils coming over between 270°C. and 300°C., the residue being a thick limpid, red-brown mass.

DESCRIPTION OF THE PROCESS.

The Company in their prospectus state that the solution may either be applied with a wire brush after heating to 65°C. to 94°C. or that the timber may be soaked in a warm solution. In the first case two or even three coats of the fluid should be given to the timber, the solution being allowed to dry before the second and third coats are applied. If treated by the Open Tank method, the solution should be heated to 80°C., or better to 95°C., and the timber be allowed to remain in the solution for 5 to 15 minutes according to the size, quality and character of the timber to be impregnated.



Necessary plant required for the impregnation of sleepers by the Open Tank process.

DISCUSSION AS TO THE BEST METHODS OF TREATING TIMBER WITH CARBOLINEUM OILS.

From experiments carried out by Monsieur Henry, he found that the amount of absorption by oak and beech after being immersed in the solution for 10 minutes at 60°C., was not materially increased by allowing the timber to remain in the solution double that period. He also ascertained that raising the temperature to 80° C. and over in no way affected the amount of absorption

DEPTH OF PENETRATION OF THE SOLUTION INTO INDIAN TIMBERS.

From experiments carried out with a variety of Indian timbers it was found that no general rule could be laid down as to the period of immersion necessary and that each species or group of species would have to be treated on their merits.

Experiments were carried out with twelve Indian timbers, some of which were hard and close grained, others moderately so and the rest of open soft texture. One set of woods was given two coats of the warm solution at intervals of a week, and the other sets were immersed in a warm solution for 10 minutes.

Plate II represents, in the upper line, two pieces (12″ × 4″ × 4″) of *Pterocarpus macrocarpus* (Burman Padauk), the left hand one has been immersed, while the right hand one has been given two coats of paint. They were cut open after treatment to ascertain the depth to which the solution had penetrated, the two small sections shown on each side of the upright specimens present the sectional end cut out of the main blocks. In the same way the two lower specimens (12″ × 4″ × 4″) demonstrate the depth to which the oil has penetrated into "Sal". It will be seen by examining these photographs that the solution in all cases has only penetrated about one-sixteenth of an inch into the sides and one-eighth into the ends, also that the depth to which the solution has penetrated into specimens *a* and *c* is slightly greater on one side than the other. The latter fact is attributed to the wood having rested on the bottom of the immersion tank and thus having been less effected on the lower surface than on the side over which the solution could act more freely.

From a careful examination it was found that in the case of both the immersed pieces the solution had penetrated slightly further into the timber than was the case with the painted specimens. The above results clearly demonstrate that in the case of hard woods the solution having only acted on a very thin outer layer of the timber, a longer period of immersion would be necessary to protect them from decay. As will be seen by the results of other experiments, this is not the case with softer woods.

Plate III, specimens *a* and *b* demonstrate in a similar manner the depth of penetration of the oil into the timber of *Picea Morinda,* the Himalayan spruce (12″ × 4″ × 4″) when immersed and when painted while Sections *c* and *d* are specimens of *Boswellia serrata* (12″ × 4″ × 4″). Here we have timbers decidedly softer than "Padauk" or

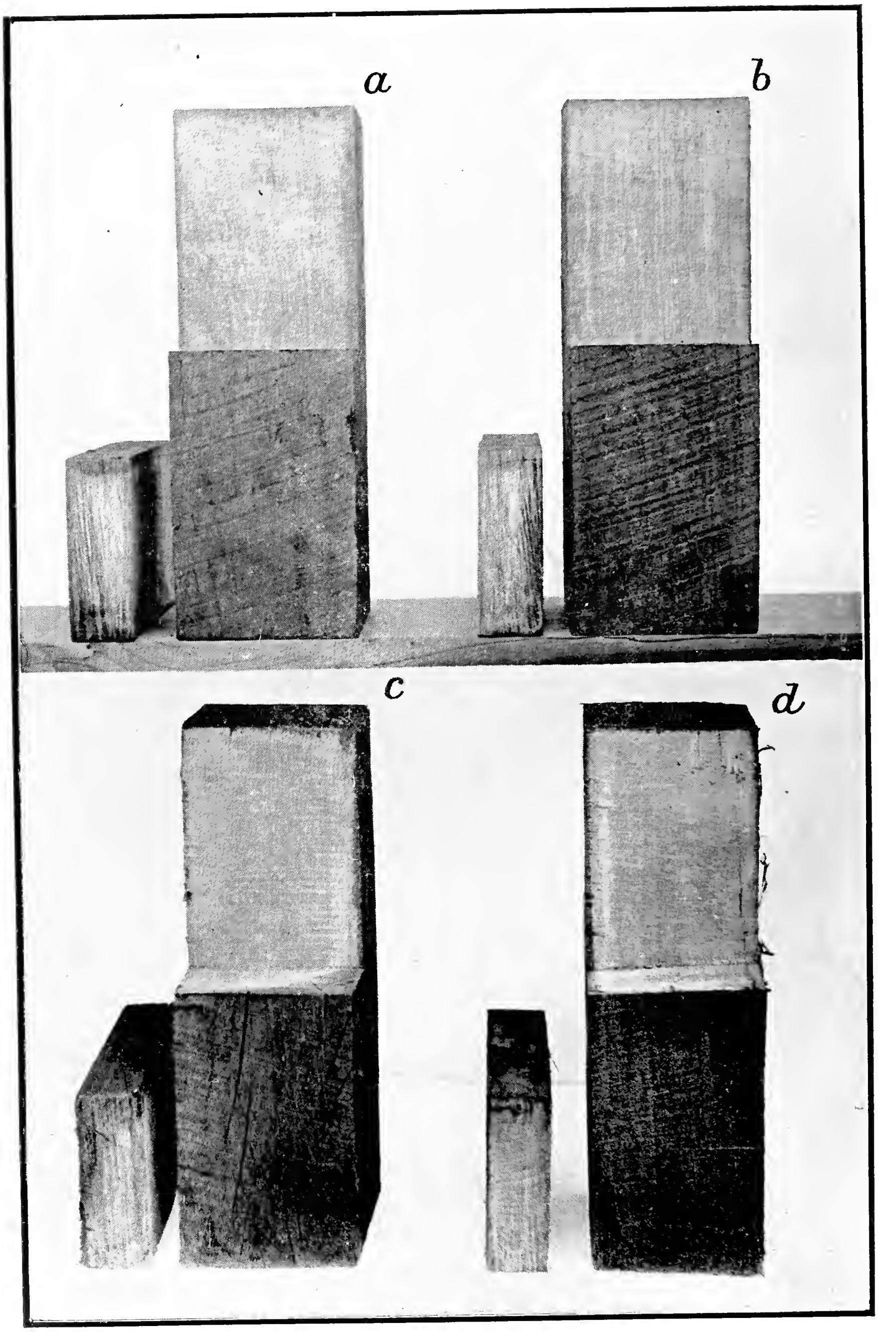


Photo-Mechl. Dept., Thomason College, Roorkee.

Degree of penetration into the wood of **a** and **b** *Pterocarpus macrocarpus* and **c** and **d** *Shorea robusta*—(i) immersed in, (ii) painted over with **Avenarius carbolineum**.

[To face Plate III.

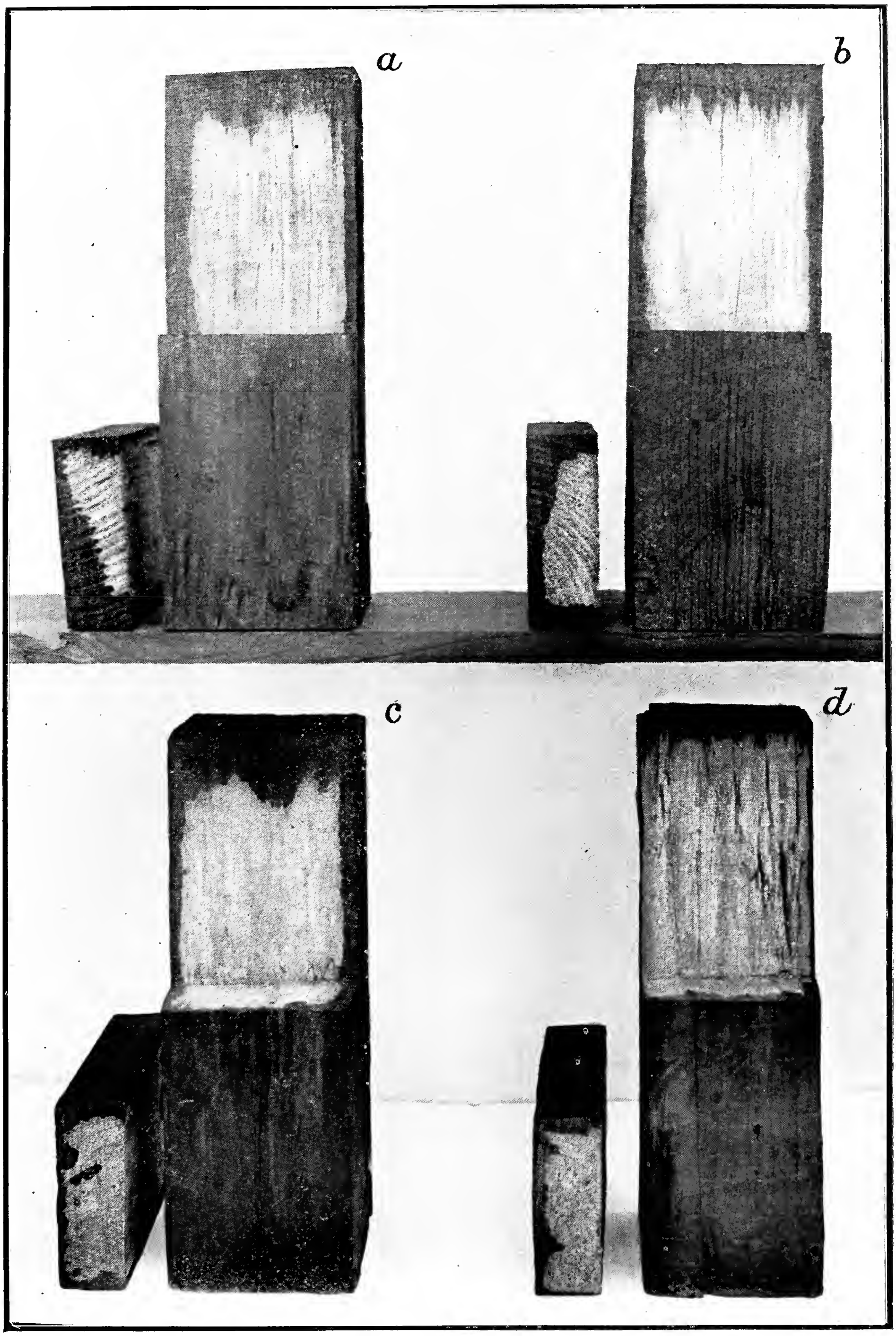


Photo-Mechl. Dept., Thomason College, Roorkee.

Degree of penetration into the wood of **a** and **b** *Picea Morinda* and **c** and **d** *Boswellia serrata*—(i) immersed in, (ii) painted over with **Avenarius carbolineum.**

[To face Plate II, between pages 56 & 57.

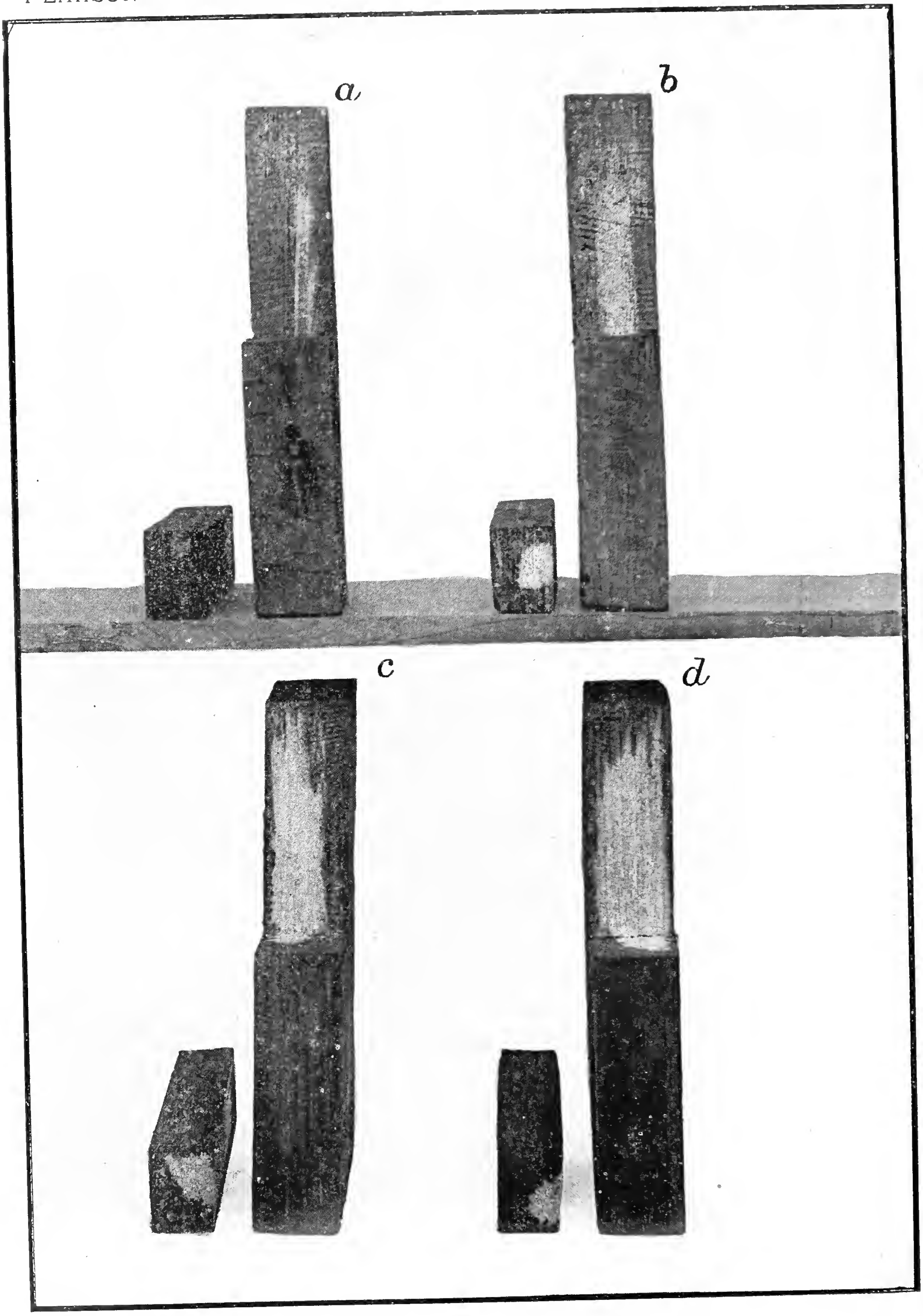


Photo-Mechl. Dept., Thomason College, Roorkee.

Degree of penetration into the wood of a and b *Pinus longifolia* and c and d *Pinus excelsa* (i) immersed in, (ii) painted over with **Avenarius carbolineum.**

[To face page 57.

"Sal" and the depth to which the antiseptic has penetrated is in proportion greater. Specimens *a* and *c* were immersed, while the specimens *b* and *d* were treated with the brush. Both the immersed specimens show greater absorption than those on which the antiseptic was only painted, while in all four cases a very fair portion of the outer tissue has been thoroughly impregnated. Were the timbers so treated destined to be used as fencing posts, the amount of absorption would be sufficient to protect them from decay, though were they intended for sleeper woods the period of immersion would probably have to be extended until the antiseptic had had time to sink deeper into the timber.

Plate IV, specimens *a* and *b* exhibits the penetration of Avenarius Carbolineum oil into the timber of *Pinus longifolia,* the Chir of the Himalayas and specimens *c* and *d* into that of *Pinus excelsa,* the blue pine, both fairly soft woods. In this case it must be remembered that the specimens treated are exactly half the size (12″ × 4″ × 2″) of those shown on Plates II and III so that the depth of penetration in this instance appears greater than in the case of the larger specimens; on the other hand, the solution has penetrated to the centre of the immersed "Chir" specimen and also has sunk well into the Blue Pine timber. In both cases the immersed specimens *a* and *c* show greater absorption than those treated with the brush *b* and *d*.

The above results clearly indicate that 10 minutes' immersion in a warm solution is insufficient for hard woods. It will probably be necessary to treat the conifers for 15 minutes to half an hour, the moderately harder species for a period varying from two hours and upwards and very hard timber for 12 to 24 hours according to the density of the wood and the size of the scantlings under treatment.

AMOUNT OF ABSORPTION OF THE OIL BY INDIAN TIMBERS.

When calculating the quantity of a solution absorbed by a B. G. sleeper based on data obtained by treating small pieces of timber, two factors must be taken into account; (*i*) the volume of the treated piece, (*ii*) the superficial area over which absorption takes place. Presuming the solution penetrates to the centre of the timber, the calculations have to be based on volume; on the other hand, if only the outer layers of the treated pieces are affected, the calculations must be based on the superficial area of the piece under treatment and not according to the volume

of the piece. The following table demonstrates the varying quantities absorbed by different species after immersion for ten minutes in a solution, heated to a few degrees below boiling point. As the solution did not in all cases penetrate to the centre of the specimen, the calculations have been based, not only on the cubical contents of the treated piece but also on its superficial area :—

Register No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before immersion.	Weight of specimen after immersion.	Weight of solution absorbed by specimen.	Absorption per superficial surface in sq. ft.	Absorption per cub. ft.
		sq. ft.	cub. ft.	lbs. oz.	lbs. oz.	lbs. oz.	oz.	oz.
1	*Boswellia serrata.*	1·55	0·13	4 6	4 11	0 5	3·23	37·7
3	*Pinus longifolia.*	1·11	0·06	1 9	2 0	0 7	6·31	116·6
5	*Pinus excelsa.*	1·11	0·06	1 7	1 9	0 2	1·80	33·3
7	*Picea Morinda.*	1·55	0·11	3 3	3 6	0 3	1·93	27·3
9	*Abies Pindrow*	1·11	0·06	1 15	2 1	0 2	1·80	33·3
11	*Pterocarpus macrocarpus.*	1·55	0·12	7 9	7 11	0 2	1·29	16·6
13	*Bombax malabaricum.*	1·55	0·12	2 8	2 11	0 3	1·93	25·0
15	*Bauhinia retusa.*	1·55	0·12	5 8 5 15	6 1	0 2	1·29	16·6
17	*Dipterocarpus tuberculatus.*	1·55	0·11	6 0	6 1	0 1	0·65	9·09
19	*Anogeissus latifolia.*	1·11	0·06	3 6	3 8	0 2	1·80	33·3
21	*Odina Wodier.*		(No	estimate	made.)			
23	*Shorea robusta*	1·55	0·11	7 4	7 5	0 1	0·65	9·09

The above figures demonstrate that the amount of absorption by a hardwood such as *Shorea robusta* (Sal) is hardly one-third that of the softer timbers. The conifers would be expected to absorb about the same quantity of the oil and this was actually the case with *Pinus excelsa, Picea Morinda* and *Abies Pindrow,* while *Pinus longifolia* absorbed more than double the amount per square foot. This variation is not easy to explain ; it is partly attributed to the excessive dryness of the timber when treated and to slight splits occurring in the specimen.

COST OF TREATMENT.

The cost of treatment must vary with the amount of oil absorbed by different species, while the cost of the necessary apparatus, which is extremely simple, together with fuel, labour, etc., may be put at 1 anna per B. G. sleeper. No figures are available as to the cost of treating sleepers in India on a large scale with this antiseptic; the only data available are therefore taken from the experiments made on a laboratory scale. Taking the wholesale cost of the oil at R1-10-0 per gallon, if imported on a large scale straight from Europe, and the weight per gallon as 11 lbs. 4 oz. (180 oz.), the cost per oz. works out to 0·15 anna. A B. G. sleeper ($9{\cdot}5' \times 10'' \times 5''$) is approximately 24·4 square feet or contains 3·3 cubic feet. Taking the percentage of absorption by the various timbers as given in the previous table, the cost of treating B. G. sleepers of those species works out as follows:—

Species.	Cost of processing.	Cost of oil absorbed by a B. G. sleeper per superficial area in sq. ft.	Cost of oil absorbed by a B. G. sleeper per cub. ft.	Total cost of treating a B. G. sleeper based on superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete impregnation.
	anna.	annas.	annas.	annas.	annas.
Boswellia serrata	1	11·8	18·6	12·8	19·6
Pinus longifolia	1	23·1	57·7	24·1	58·7
Pinus excelsa .	1	6·6	16·5	7·6	17·5
Picea Morinda .	1	7·1	13·5	8·1	14·5
Abies Pindrow .	1	6·6	16·5	7·6	17·5
Pterocarpus macrocarpus.	1	4·7	8·2	5·7	9·2
Bombax malabaricum.	1	7·1	12·3	8·1	13·3
Bauhinia retusa .	1	4·7	8·2	5·7	9·3
Dipterocarpus tuberculatus.	1	2·4	4·5	3·4	5·5
Anogeissus latifolia.	1	6·6	16·5	7·6	17·5
Shorea robusta .	1	2·4	4·5	3·4	5·5
Average .	1	7·55	16·09	8·55	17·09

Practically in no instance did the solution penetrate completely through the timber after immersion for 10 minutes, and as it most certainly would not do so were the timber under treatment of the size of a B. G. sleeper, the correct figures to take are those based on superficial absorption and not those calculated according to volume.

The above figures must, however, be taken with extreme caution and can only be used as a rough guide to the cost of treating the various species of timber, the danger of accepting such figures as final is demonstrated by the case of *Pinus longifolia*, the cost of treating which works out to 24·1 annas per B. G. sleeper.

Estimates for oak and beech, based on Indian prices of Carbolineum, work out to about 7 annas for treating a B. G. sleeper, a by no means excessive rate as compared with Creosote.

Further Experiments with *Dipterocarpus Tuberculatus* Timber.

With a view to ascertain the period of immersion necessary for "In" (*Dipterocarpus tuberculatus*) timber in order to preserve it from decay, as also to determine the amount of the solution required for treating the timber, the cost at the same time being kept within working limits, a further set of experiments were carried out by treating cubes $12'' \times 3'' \times 3''$ in size, by immersion, during varying periods of time. In conjunction with the above tests another experiment was carried out to ascertain the excess amount of the antiseptic absorbed by allowing the timber to remain in the fluid while cooling down. Seven blocks of timber cut to exact size were prepared, the first was immersed for 15 minutes in a hot solution of *Avenarius Carbolineum,* and allowed to cool in the fluid for another 45 minutes, the second was allowed to stay in a hot solution for an hour and then was removed, the third was heated for an hour and allowed to remain another hour in the fluid while it was cooling down; the fourth and fifth were similarly treated but allowed to remain for two hours and three hours respectively in the cooling solution; the sixth was given 8 hours and the seventh 23 hours immersion over and above the hour in the hot fluid.

The quantity of the antiseptic absorbed by the various pieces works out as follows :—

Specimen No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before immersion.		Weight of specimen after immersion.		Weight of solution absorbed by specimen.	Absorption per superficial area in sq. ft.	Absorption per cub. ft.
		sq. ft.	cub. ft.	lbs.	oz.	lbs.	oz.	oz.	oz.	oz.
1	*Dipterocarpus tuberculatus* (Burman "In" wood.)	1·125	0·062	3	3·37	3	4·26	0·89	0·79	14·51
2		1·125	0·062	3	3·33	3	3·76	0·43	0·38	6·88
3		1·125	0·062	3	1·30	3	3·80	2·50	2·20	40·00
4		1·125	0·062	3	2·76	3	7·75	4·99	4·40	79·84
5		1·125	0·062	3	3·76	3	7·92	4·16	3·69	66·56
6		1·125	0·062	3	3·50	3	8·75	5·26	4·67	84·16
7		1·125	0·062	3	1·50	3	9·87	8·37	7·44	135·00

The most interesting feature shown by the above figures is the amount of absorption of the oil by specimens Nos. 1 and 2. The first specimen, it will be remembered, was treated for 15 minutes in the hot solution and allowed to remain a further 45 minutes in the fluid while it cooled down, the second was immersed for 60 minutes in the hot solution and then removed. The absorption by No. 1 was 0·89 oz. as against 0·43 by No. 2 or slightly over double the amount; this was no doubt due to the suction brought into play by the vacuum and caused by contraction on cooling. As regards the depth to which the oil penetrated into the various pieces of wood, in Nos. 1 and 2 it was hardly more than one-sixteenth of an inch, the distance being slightly greater in the case of No. 1 than in the case of No. 2, in No. 3 it was one-fourth on the sides and one-half at the ends, while owing to the large wood vessels in this timber the fluid had penetrated down the channels so that on the specimen being cut open, the surface appeared to be dotted with small dark points, showing sections of the cells impregnated with oil. Nos. 4 and 5 on being sawn open showed a greater penetration of the fluid than was the case in No. 3, the surface of the cut presenting a blotchy appearance; No. 6 was similar in appearance to Nos. 4 and 5 but more heavily impregnated, while No. 7, which had been in the solution for 24 hours, was heavily saturated throughout.

RELATIVE COST.

Assuming that this antiseptic can be relied upon to protect the timber from decay for a reasonable period of time, the economic position of affairs resolves itself into the question as to whether the cost of the quantity of the solution, just sufficient to preserve it, taken up by a B. G. sleeper, is within the price we can afford to pay for such work. To solve this problem we must know what we can afford to pay for treating a sleeper. Taking, for example, the timber here experimented upon, namely "In" wood, the cost of extraction and conversion may be put at ₹2-0-0, the royalty may be put at 4 annas per cubic foot or 13 annas 2·5 pies per B. G. sleeper, a total of ₹2-13-2·5 pies. The total price of a treated sleeper must be below that of a first class untreated sleeper, for instance "Sal," the price of which may be put at ₹4-2-0. We have therefore a margin of from ₹1-0-0 to ₹1-5-0, of which at least two-thirds may go to treatment.

From the percentage of absorption given in the above table and taking the price of *Avenarius Carbolineum* as 0·15 anna per oz., and a B. G. sleeper as 3·3 cubic feet or 24·4 superficial feet, the following would be the cost of treating the sleepers, according to the period of immersion and quantity of oil absorbed :—

Serial No.	Species.	Cost of processing.	Cost of oil absorbed by a B. G. sleeper per superficial area in sq. ft.	Cost of oil absorbed by a B. G. sleeper per cub. ft.	Total cost of treating a B. G. sleeper based on the superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete impregnation.
		anna.	annas.	annas.	annas.	annas.
1	*Dipterocarpus tuberculatus* (Burman "In" wood.)	1	2·89	7·18	3·89	8·18
2		1	1·39	3·40	2·39	4·40
3		1	8·05	19·80	9·05	20·80
4		1	16·10	39·52	17·10	40·52
5		1	13·50	32·94	14·50	33·94
6		1	17·09	41·65	18·09	42·65
7		1	27·23	66·82	28·23	67·82

In the above table, calculations have been made based on the assumption of partial or superficial absorption and also assuming complete impregnation. As only specimen No. 7 was completely impregnated and the others had only the outer layers of the timber affected by the oil, it is obvious that we must be guided by the cost based on superficial absorption. The cost of treating Nos. 1 and 2 come well within the economic limit of working; on the other hand, the depth of penetration of the oil was hardly sufficient to guarantee protection to the timber. No. 3 was more heavily impregnated and to a greater depth. Without a prolonged trial it cannot be said with certainty whether this specimen was sufficiently saturated to preserve it from decay, but probably it would be so. The cost works out to 9·05 annas for a B. G. sleeper and so well within the working limit.

Before leaving this question it is necessary to again remember that such laboratory experiments carried out on a small scale, are by no means conclusive, and that calculations of cost of treatment based on work carried out on a very limited scale generally give figures considerably higher than if the work were done on a large commercial scale.

EUROPEAN AND INDIAN RECORDS OF AVENARIUS CARBOLINEUM.

Avenarius Carbolineum has been long on the market in France, while timbers treated with this oil have repeatedly proved its value. Professor Henry, Deputy Director of the National Forest School of France, has carried out exhaustive experiments with Carbolineum oil, the results of which are published in his treatise entitled "La Préservation des Bois contre la Pourriture." He laid down treated and untreated beech, oak, poplar and a variety of pine posts in the ground as also in mines. After three years the untreated post had perished, while the treated timber remained sound. The result of his research in this direction induced M. Dubois, Ingénieur des Ponts et Chaussées to lay down 7,000 sleepers treated with this oil on the narrow gauge line to Toul, and there appears to be no reason why the experiment should not turn out a success.

The Company in their prospectus state that *Avenarius Carbolineum* was used in the construction of the dock of the Union Carbide Works, Sault State, Mane, Mich: by the Bay Counties Power Co., St. Francisco, on the Kaiser Wilhelm Canal and many other places in Europe and America, and in all cases it proved efficient in preserving the timber.

Several reliable records are available as to the results of experiments made in India with this oil. The Secretary to the Government of Bengal, Public Works Department, reports on this antiseptic as follows :—

"Engineers of different circles of this Province were asked in August 1906 to try the preparation and submit a report of the result. It has been experimented on throughout the Province and the inference that may be drawn is that it is very useful in keeping away white-ants, but is not always entirely effective."

Another report is available of tests carried out by the Public Works Department in the United Provinces. The Under-Secretary of that Department reporting on the subject to the Government of India, states :—

"Experiments were made in various divisions of the Province where white-ants are prevalent. In one case the effect of the preparation was tried on a portion of a 'Sirki' ceiling which had many times been destroyed by white-ants, and it was found that the protection was perfect. In most cases, however, the experiment took the form of burying pieces of different kinds of wood which had been treated with Carbolineum along with pieces not so treated in the nests of white-ants. The pieces of wood were dug up after 3 months or more and in every case, except that of Cawnpore, it was found that Carbolineum had given complete protection, whilst the pieces which had not been treated with the preparation were destroyed."

Another report comes from the Superintending Engineer, 3rd Circle, Punjab, in which details of six experiments are given, all of which proved successful. In conclusion he writes as follows :—

> "I personally think the solution is all that the manufacturers claim for it, and have unhesitatingly recommended it to every one I thought the solution would be useful to".

He further compares the cost of *Avenarius Carbolineum* with coal-tar as 9 annas per cent. for the former and 8 annas per cent. for the latter. The other records available are those of experiments made at the Forest Research Institute, in which twelve different species (the same as those recorded above on which absorption tests were carried out) were given two coats of the solution at intervals of a week and placed upright in the ground together with untreated pieces of the same species, and kept under observation. The pieces have now been in the ground 16 months and none of the treated specimens have as yet shown

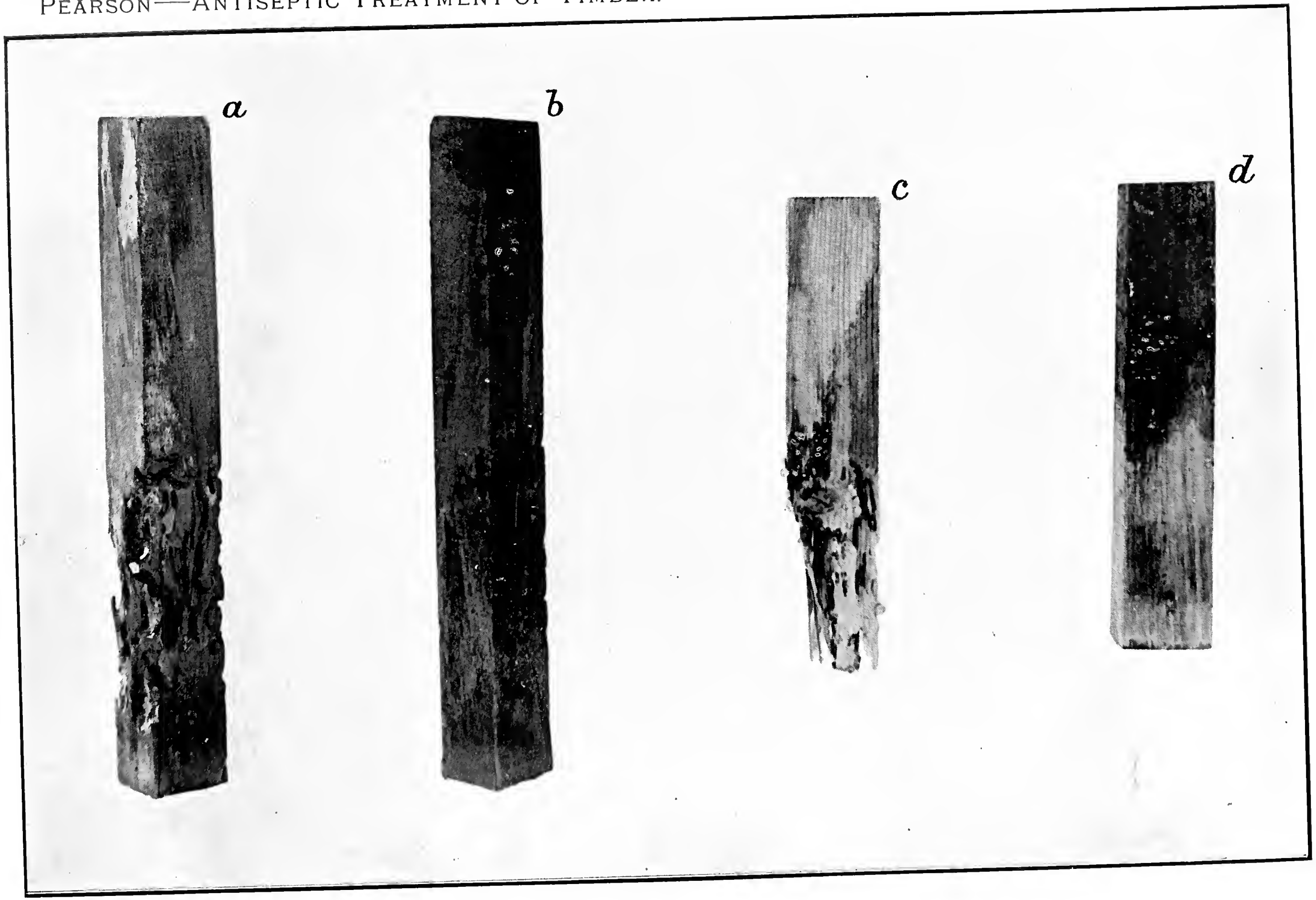


Photo-Mechl. Dept., Thomason College, Roorkee.

Result of white-ant attacks on untreated pieces **a** and **c** of *Boswellia serrata* and *Picea Morinda* respectively as compared with pieces **b** and **d** treated with **Avenarius carbolineum**, which remained unattacked.

signs of decay nor have they been attacked by white-ants, while several of the treated pieces have perished.

Plate V, specimens *a* and *b* show pieces of untreated and treated *Boswellia serrata,* and specimens *c* and *d* pieces of *Picea Morinda,* which had been in the ground for two and one month respectively.

The condition of the specimens up to date is given below :—

Register No.	Species.	TREATED.			UNTREATED.		
		Date on which laid down.	Date of inspection.	Condition.	Date on which laid down.	Date of inspection.	Condition.
1 and 2	*Boswellia serrata* .	12th June 1909.	17th Aug. 1910.	Sound .	12th June 1909.	12th Aug. 1909.	Destroyed by white-ants and removed on 12th August 1909.
3 and 4	*Pinus longifolia* .	Do. .	Do. .	Do. .	Do. .	17th Aug. 1909.	Sound.
5 and 6	*Pinus excelsa* .	Do. .	Do. .	Do. .	Do. .	Do. .	Do.
7 and 8	*Picea Morinda* .	Do. .	Do. .	Do. .	Do. .	1st Oct. 1909.	The lower portion entirely destroyed by white-ants. The piece was removed on 1st October 1909.
9 and 10	*Abies Pindrow* .	Do. .	Do. .	Do. .	Do. .	17th Aug. 1910.	White-ants working over the surface.
11 and 12.	*Pterocarpus macrocarpus.*	Do. .	Do. .	Do. .	Do. .	Do. .	Sound.
13 and 14.	*Bombax malabaricum.*	Do. .	Do. .	Do. .	Do. .	Do. .	Badly attacked by white-ants, piece removed on 17th August 1910.
15 and 16.	*Bauhinia retusa* .	Do. .	Do. .	Do. .	Do. .	Do. .	Sound.
17 and 19.	*Dipterocarpus tuberculatus.*	Do. .	Do. .	Do. .	Do. .	Do. .	Do.
19 and 20.	*Anogeissus latifolia*	Do. .	Do. .	Sound though cracked.	Do. .	Do. .	White-ants working over the surface.
21 and 22.	*Odina Wodier* .	Do. .	Do. .	Sound .	Do. .	Do. .	Slightly pitted by white-ants.
23 and 24.	*Shorea robusta* .	Do. .	Do. .	Do. .	Do. .	Do. .	Sound.

The above results show that three out of twelve of the untreated woods have been destroyed, three others are under process of destruction and six are still sound. On the other hand, except for slight cracks in some cases, the twelve treated specimens are intact.

B

Summary.

From what has been said in the foregoing paragraphs, it will be seen that *Avenarius Carbolineum* has many good qualities as an antiseptic. The past records are favourable and further the necessary apparatus required for treating the timber is cheap, easily moved and requires no skilled labour to work it. The most important consideration, however, is that the oil is not readily washed out by excessive moisture, and that it has a very high boiling point, and therefore is not liable to evaporation in a hot climate.

The cost of treatment is somewhat high, though by varying the period of immersion it is possible to regulate the quantity of the oil absorbed and thus adjust the cost within working limits. Whether the amount of the solution taken up under these conditions is sufficient to protect the timber effectually can only be proved by actual trials, carried out over a considerable period of time. Definite proposals as to future experiments to be made with the preservative are given in Chapter IV, while 2,000 sleepers of five different species are now being treated with this oil, and laid down in different localities.

(5) JODELITE.

Jodelite.

A patent solution known as Jodelite* has been for some years on the market and has attracted considerable attention in various parts of the world. Its constituents are unknown, but from its appearance it is no doubt largely composed of the heavier Creosote oils.

Method of Treatment.

Like *Avenarius Carbolineum* it is either applied with a wire brush or by the immersion of the timber in the solution. Directions for its use state that two coats of the solution are required if applied with the brush, and that the period of immersion, in the case of treatment by the Open Tank method, should be 10 to 40 minutes according to the density of the timber; in both cases the solution should be heated to 82° to 94°C.

* The solution can be procured from Joseph Dee & Sons, 5 Cross Street, Manchester, England, the cost landed in India being R2-11 per gallon (1 gallon of the solution weighs 10 lbs. 14½ oz.)

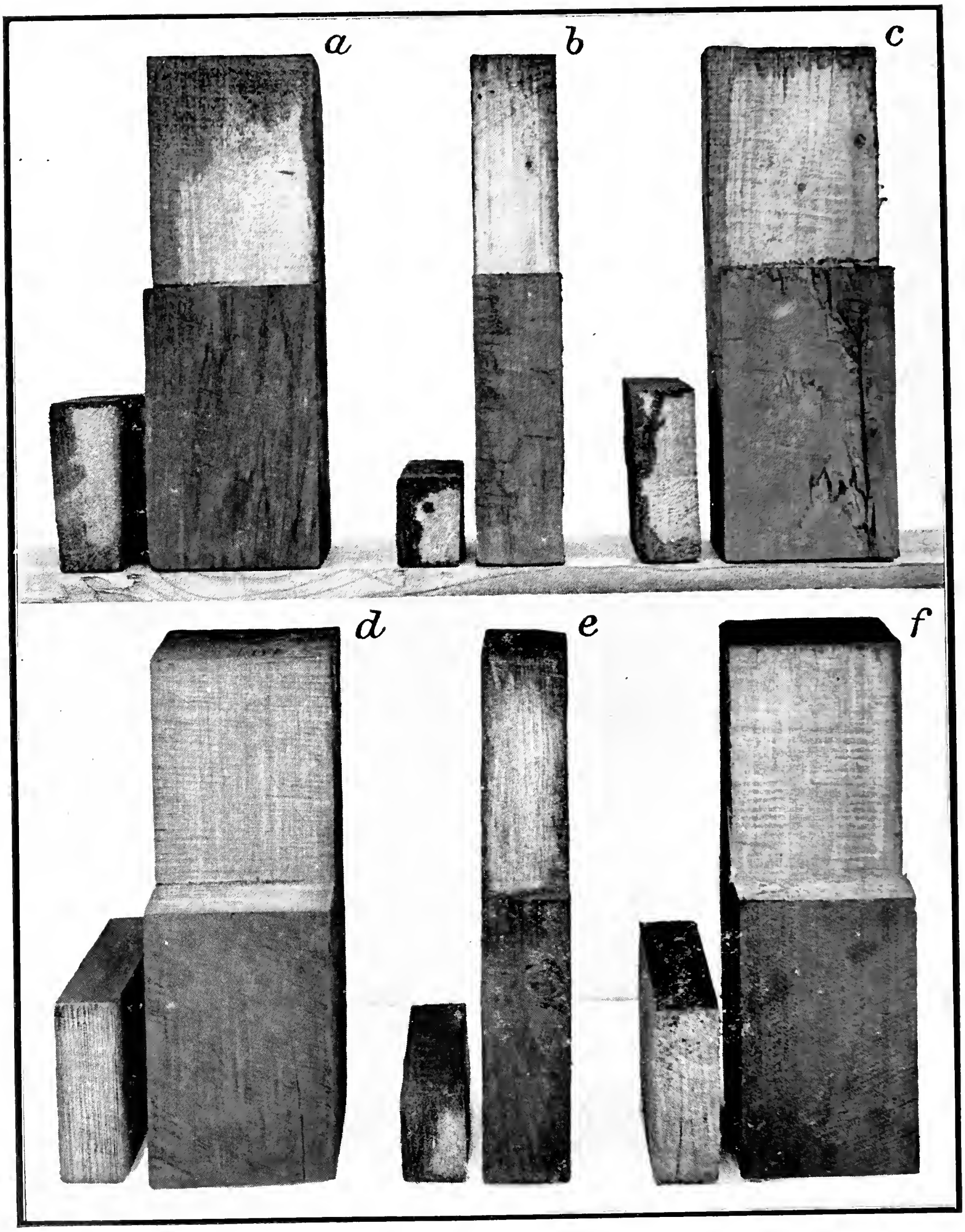


Photo-Mechl. Dept., Thomason College, Roorkee.

Degree of penetration of **Jodelite** into the wood of **a** *Boswellia serrata*, **b** *Pinus excelsa*, **c** *Picea Morinda*, **d** *Pterocarpus macrocarpus*, **e** *Pinus longifolia* and **f** *Shorea robusta*, after immersion in this antiseptic.

[To face Page 67.

ABSORPTION OF THE SOLUTION BY INDIAN TIMBERS.

From experiments carried out at the Forest Research Institute it was found that a period of immersion of 15 minutes in a hot solution was insufficient in the case of hard woods, such as *Dipterocarpus tuberculatus* ("In" wood), *Anogeissus latifolia* and *Pterocarpus macrocarpus* (Burman Padauk), and that it would have to be prolonged to several hours at least, otherwise only a very thin shell of the timber would be affected which would be quite insufficient to ensure protection for any length of time.

Plate VI, specimens *a, b* and *c* illustrate sections of *Boswellia serrata, Pinus excelsa* and *Picea Morinda* respectively which have been immersed for 15 minutes in Jodelite, heated to just below boiling point, while specimens *d, e* and *f* illustrate sections of *Pterocarpus macrocarpus* (Burman Padauk), *Pinus longifolia* and *Shorea robusta* (Sal). *a* is a soft wood; in this case the oil has saturated the outer tissue to a considerable depth. *b, c* and *e* are conifers, which have probably been sufficiently impregnated for use as posts but not for sleeper purposes, while the *d* and *f* show hardly one-eighth penetration and would therefore require more drastic treatment. The remarks made on page 57 as to the method of calculating the absorption of *Avenarius Carbolineum* by various timbers apply equally to *Jodelite*. Experiments similar to those carried out with Carbolineum oil were carried out with Jodelite, the only difference being that the timber in this case remained 15 minutes in the solution as compared with 10 minutes in the case of Carbolineum. The quantity of the solution absorbed by the different species is tabulated below:—

Register No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before treatment.	Weight of specimen after treatment.	Weight of solution absorbed.	Absorption per superficial surface.	Absorption per cub. ft.
		sq. ft.	cub. ft.	lbs. oz.	lbs. oz.	lbs. oz.	oz.	oz.
1	*Boswellia serrata* .	1·55	0·11	4 2	4 7	0 5	3·23	45·55
3	*Pinus longifolia* .	1·11	0·06	1 11	1 14	0 3	2·71	50·0
5	*Pinus excelsa* . .	1·11	0·06	1 8	1 9	0 1	0·91	16·66

Register No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before treatment.		Weight of specimen after treatment.		Weight of solution absorbed.		Absorption per superficial surface.	Absorption per cub. ft.
		sq. ft.	cub. ft.	lbs.	oz.	lbs.	oz.	lbs.	oz.	oz.	oz.
7	*Picea Morinda* . .	1·55	0·11	3	8	3	10	0	2	1·29	18·18
9	*Abies Pindrow* . .	1·11	0·06	1	11	1	12	0	1	0·91	16·66
11	*Pterocarpus macrocarpus.*	1·55	0·13	7	10	7	11	0	1	0·65	7·69
13	*Bombax malabaricum* .	1·55	0·12	2	9	2	15	0	6	3·88	50·0
15	*Bauhinia retusa* . .	1·55	0·12	6	0	6	2	0	2	1·29	16·66
17	*Dipterocarpus tuberculatus.*	1·55	0·11	5	15	6	0	0	1	0·65	9·09
19	*Anogeissus latifolia* .	1·11	0·06	3	7	3	8	0	1	0·91	16·66
21	*Odina Wodier* . .	No experiments made.									
23	*Shorea robusta* . .	1·56	0·12	7	6	7	7	0	1	0·65	8·43

Comparing the above figures for Jodelite with those obtained for *Avenarius Carbolineum* (page 58) the quantity absorbed is slightly less; in other words, the penetration has been on the whole not so deep, the only noticeable exceptions being Nos. 1 and 13, both soft woods. Here again, the harder species have not been left long enough in the solution to afford proper protection to the timber.

COST OF TREATMENT.

The cost of treating a B. G. sleeper is calculated on the above percentages of absorption. The superficial area of a B. G. sleeper is taken as 24·4 square feet, and the volume as 3·3 cubic feet. The cost of the solution landed at Karachi, including freight and duty, is taken as R2-11 per gallon and its weight as 10 lbs. 14·5 oz. per gallon. The cost of processing is put at 1 anna per sleeper.

On the above data the cost of pickling a B. G. sleeper of the various species works out as follows :—

Species.	Cost of processing.	Cost of solution absorbed by a B. G. sleeper per superficial area in sq. ft.	Cost of solution absorbed per B. G. sleeper per cub. ft.	Total cost of treating a B. G. sleeper based on superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete impregnation.
	anna.	annas.	annas.	annas.	annas.
Boswellia serrata	1	19·7	37·6	20·7	38 6
Pinus longifolia . . .	1	16·5	41·3	17·5	42·3
Pinus excelsa	1	5·6	13·7	6·6	14·7
Picea Morinda	1	7·9	15·0	8·9	16·C
Abies Pindrow	1	5·6	13·7	6 6	14·7
Pterocarpus macrocarpus . .	1	4·0	6·3	5·0	7·3
Bombax malabaricum . .	1	23·7	41·3	24·7	42·3
Bauhinia retusa . . .	1	7·9	13 7	8·9	14·7
Dipterocarpus tuberculatus .	1	4·0	7·5	5·0	8·5
Anogeissus latifolia . . .	1	5·6	13·7	6·6	14·7
Shorea robusta	1	4·0	6·9	5·0	7·9
Average .	1	9·68	19·07	10·68	20·07

Comparing the cost of Jodelite treatment in the case of B. G sleepers with that of Avenarius Carbolineum, there is a small difference in favour of the latter, as the calculations based on superficial area give 10·68 annas for the former as compared to 8·55 annas for the latter, while those based on the volume of a B. G. sleeper work out to 20·07 annas as the cost of treating with Jodelite as compared with 17·09 annas for Carbolineum. In comparing the above figures it must also be remembered that the period of immersion was 5 minutes longer in the case of the Jodelite experiments than was the case in the Carbolineum tests.

Both sets of figures are probably too high, as by treating only small specimens there is in proportion to the volume a greater loss by drip, etc., than would be the case when treating large numbers of sleepers. Again the two sets of figures vary considerably; in the cases in which the timber was only affected partially, the figures of cost, based on the superficial absorption, are far more correct than those based on volume, and in actual practice this would also hold good in most cases where the timber was treated by the Open Tank method.

INDIAN RECORDS OF TIMBER TREATED WITH JODELITE.

In 1908 sleepers treated with Jodelite were laid down at the instigation of the Forest Department by the Burma Railways near Pyinmana together with untreated sleepers of the same species. The results as noted on the 1st October 1910 were as follows :—

No.	Species.	SLEEPERS TREATED WITH JODELITE.			UNTREATED SLEEPERS.		
		No. of sleepers treated.	Date of laying in open line.	Condition on 1st Oct. 1910.	No. of sleepers.	Date of laying in open line.	Condition on 1st October 1910.
1	*Dipterocarpus tuberculatus.*	10	Apl. 1908	Sound .	10	15th Apl. 1907.	One removed in July 1910, one doubtful, the rest in order.
2	*Dipterocarpus alatus.*	10	Do.	Sound but somewhat cracked.	10	Do.	One removed in 1909, the remainder in order.
3	*Albizzia odoratissima.*	10	Do.	Sound .	10	Do.	One removed in July 1910, one doubtful, the rest in order.
4	*Homalium tomentosum.*	10	Do.	Do.	10	Do.	Eight removed in 1908-09, one in 1910, the other doubtful.
5	*Schleichera trijuga.*	10	Do.	Do.	10	Do.	Seven removed in July 1910.
6	*Terminalia belerica*	10	Do.	Five removed in July 1910, the rest in order.	10	Do.	All removed in 1909.
7	*Terminalia tomentosa.*	10	Do.	Sound .	10	Do.	All sound.
8	*Lagerstrœmia tomentosa.*	10	Do.	Do.	10	April 1908.	Nine sound; one doubtful.

These sleepers were again inspected by the writer of this Note in February 1911 and found to be in the same condition.

Another set of experiments was commenced in 1909 at the Forest Research Institute, Dehra Dun, in which samples of the twelve species of timber were treated by immersion for 15 minutes in a warm solution of Jodelite. These were placed upright in the ground together with untreated specimens of the same species and sawn from the same logs

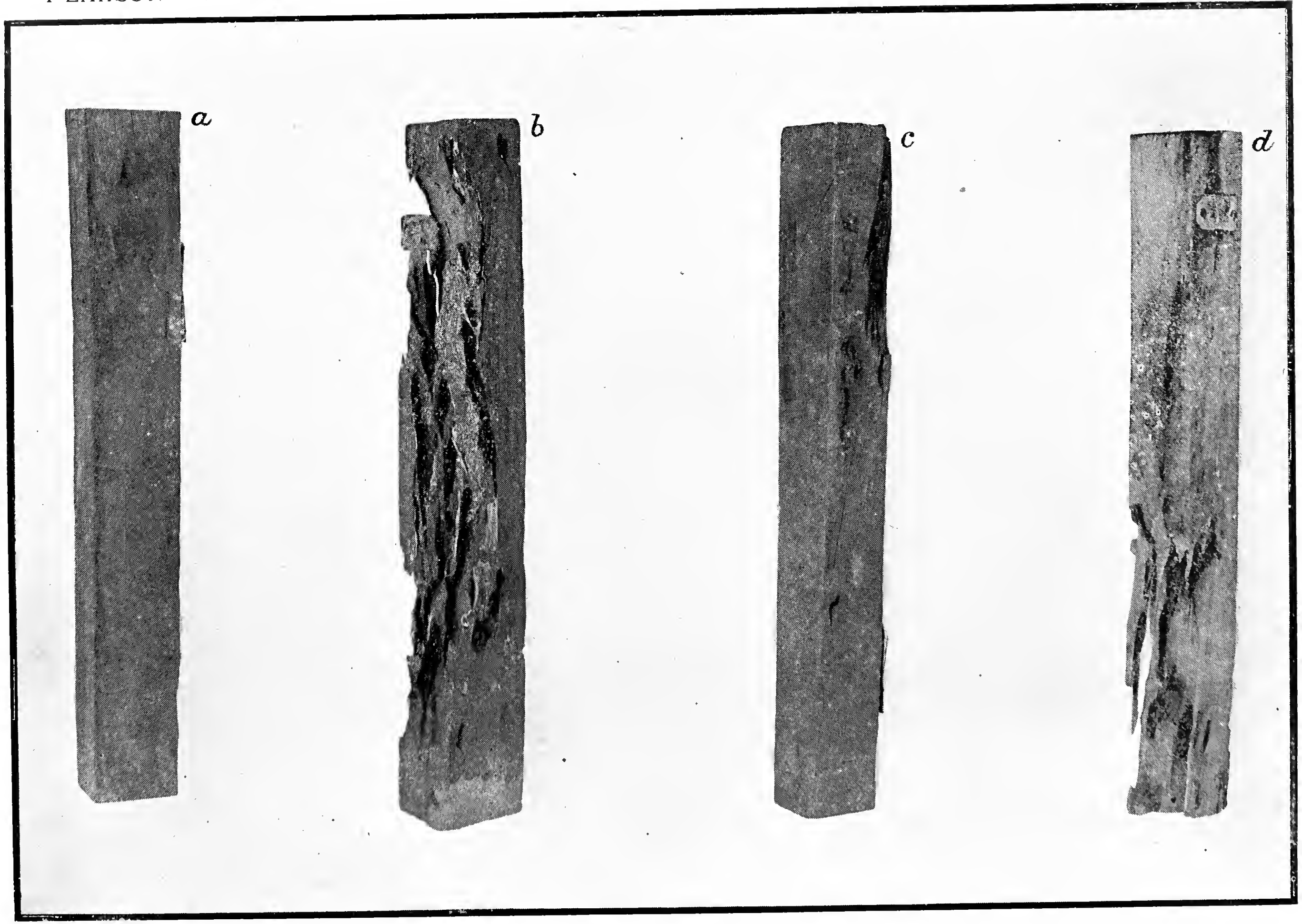


Photo-Mechl. Dept., Thomason College, Roorkee.

Result of white-ant attacks on untreated pieces **b** and **d** of *Boswellia serrata*, and *Odina Wodier*, respectively as compared with the pieces **a** and **c** treated with **Jodelite**, which remained unattacked.

as the treated specimens. The condition of the treated and untreated posts when last inspected was as follows :—

Register No.	Species.	TREATED.			UNTREATED.		
		Date on which laid down.	Date of inspection	Condition.	Date on which laid down.	Date of inspection.	Condition.
1 and 2	*Boswellia serrata*	14th July 1909.	18th Aug. 1910.	Sound .	14th July 1909.	1st Oct. 1909.	Completely eaten by white-ants and removed on 1st October 1909.
3 and 4	*Pinus longifolia* .	Do.	Do.	Do.	Do.	18th Aug. 1910.	Sound.
5 and 6	*Pinus excelsa* .	Do.	Do.	Do.	Do.	Do.	Do.
7 and 8	*Picea Morinda* .	Do.	Do.	Do.	Do.	Do.	Destroyed by white-ants and removed on 18th August 1910.
9 and 10	*Abies Pindrow* .	Do.	Do.	Do.	Do.	27th June 1910.	Destroyed by white-ants and removed on 27th June 1910.
11 and 12.	*Pterocarpus macrocarpus.*	Do.	Do.	Do.	Do.	18th Aug. 1910.	Sound.
13 and 14.	*Bombax malabaricum.*	Do-	Do.	Do.	Do.	15th June 1910.	Destroyed by white-ants and removed on 15th June 1910.
15 and 16.	*Bauhinia retusa* .	Do.	Do.	Do.	Do.	9th July 1910.	White-ants working over the wood.
17 and 18.	*Dipterocarpus tuberculatus.*	Do.	Do.	Do.	Do.	18th Aug. 1910.	Sound.
19 and 20.	*Anogeissus latifolia*	Do.	Do.	Do.	Do.	Do.	Attacked by white-ants.
21 and 22.	*Odina Wodier* .	Do.	Do.	Do.	Do.	1st Oct. 1909.	Much destroyed by white-ants an removed on January 1910.
23 and 24.	*Shorea robusta* .	Do.	Do.	Do.	Do.	18th Aug. 1910.	Attacked by white-ants.

From the above statements it will be seen that all the treated specimens are in good order, while of the untreated pieces it has been found necessary to remove no less than five, three others are under process of destruction and four are sound. The period during which the solution has been under trial barely exceeds one year; on the other hand, the treated timbers have successfully withstood two heavy periods of rain amounting to over 100 inches in each year.

Plate No. VII illustrates the state of treated and untreated specimens of *a* and *b* *Boswellia serrata* and *c* and *d* *Odina Wodier* after being in the ground for a period of three months. The two treated

pieces were replaced after being photographed and are still sound after 14 months' exposure.

SUMMARY.

The remarks made in summarising the possibilities of *Avenarius Carbolineum* apply with equal force to *Jodelite*. The price of the solution per gallon is somewhat higher than that of Carbolineum oil; on the other hand, the amount of oil absorbed is slightly less, thus bringing the cost of treatment to about the same for both solutions. Proposals as to future experiments with Jodelite are made in Chapter IV.

(6) ATLAS SOLUTION.

ATLAS SOLUTION.

A compound solution, known as "Atlas,"* Preservative "A" is on the market. It is advertised for the protection of timber, eradicating weeds, disinfecting drains, etc.; its composition is a secret, protected by the Patents Act. That it is poisonous is stated by its Agents, and if applied to the skin causes irritation, though only of a temporary nature.

METHOD OF TREATMENT.

The Company in their prospectus give directions as to the method of treating timber with this solution. In the case of sleepers the timber should be immersed in a 15 to 25 per cent. cold solution for 24 to 36 hours. When dry, the timber should be covered with a coat of hot coal-tar.

In the case of treating timber *in situ*, or when used as a weed-killer or as a disinfectant, solutions of varying strength are recommended.

ABSORPTION OF THE SOLUTION BY INDIAN TIMBERS.

To determine the amount of absorption by various Indian timbers, a set of experiments similar to those carried out with *Avenarius Carboli-*

* The Agents in India for the solution are W. Crowder & Co., Ltd., 37, Apollo Street, Bombay, 1, Vansittart Row, Calcutta, and Nicol Road, Karachi; and Finlay, Fleming & Co., Rangoon. The cost of "A" solution Atlas, in 5 gallon iron drums, is R16; the strength of the solution required is 5 per cent. to 25 per cent. according to the density of the timber and the use for which it is intended.

neum and *Jodelite* were made with *Atlas*. In these experiments hot coal-tar was not applied to the timber after being treated with *Atlas*, as directed in the prospectus, for had that been done no estimate could have been made as to the value of the solution as compared with other preservatives.

In the experiments above mentioned a 20 per cent. solution was taken, and the time of immersion was 24 hours, while the species of timber treated were the same as those chosen for the experiments carried out with other antiseptic solutions. The quantity of the solution absorbed by the different timbers is shown in the following table :—

Register No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before treatment.	Weight of specimen after treatment.	Weight of solution absorbed.	Absorption per superficial area in sq. ft.	Absorption per cubic foot.
		sq. ft.	c. ft.	lbs. oz.	lbs. oz.	lbs. oz.	oz.	oz.
1	*Boswellia serrata.*	1·55	0·11	3 10	7 2	3 8	36·13	509·09
3	*Pinus longifolia.*	1·05	0·05	1 10	2 12	1 2	17·14	360·00
5	*Pinus excelsa*	1·05	0·05	1 4	2 10	1 6	20·95	440·00
7	*Picea Morinda*	1·55	0·12	3 2	3 15	0 13	8·39	108·33
9	*Abies Pindrow*	1·11	0·06	1 11	2 4	0 9	8·11	150·00
11	*Pterocarpus macrocarpus.*	1·55	0·13	7 8	7 13	0 5	3·23	38·46
13	*Bombax malabaricum.*	1·55	0·12	2 6	3 14	1 8	15·48	200·00
15	*Bauhinia retusa*	1·55	0·13	6 4	7 7	1 3	12·26	146·15
17	*Dipterocarpus tuberculatus.*	1·55	0·12	6 2	6 8	0 6	3·87	50·00
19	*Anogeissus latifolia.*	1·11	0·06	3 8	3 13	0 5	4·50	83·33
21	*Shorea robusta*	1·55	0·12	6 14	7 5	0 7	4·55	58·33

The above figures, as compared with those of Creosote extracts, show very high rates of absorption; on the other hand, the solution being 80 per cent. water and 20 per cent. antiseptic, the amount of the preservative which has been taken up and which goes to protect the timber is by no means excessive. The reason of this excessive absorption is due to the greater penetrating power of water than oil and also to the much longer period of immersion, conditions which not only hold good for mixtures of water and "Atlas," but also for all antiseptics in which a salt is dissolved in water, such as sulphate of copper, or zinc chloride.

In the above set of experiments a solution of 20 per cent. Atlas "A" was used. The Home firm have since pointed out that this strength is excessive, as from recent observations a 10 per cent. to 15 per cent. solution is quite effective. They further state that in excessively damp localities cold tar should be applied after treating with the solution and that instead of hot tar being applied better results are obtained by applying it cold and mixed with about 5 per cent. kerosine.

Plate VIII exhibits various timbers treated with a 20 per cent. solution of Atlas and immersed for 24 hours. Specimen *a* illustrates a treated piece of *Boswellia serrata* ($4'' \times 4'' \times 12''$), through which the solution has completely penetrated. Specimens *b* and *c* are of *Pinus excelsa* (blue pine) and *Picea Morinda* (spruce), into which the solution has penetrated $\frac{1}{2}''$ at the end and $\frac{1}{4}''$ on one side, the other side when immersed was touching the bottom of the tank so that the solution could not circulate freely and consequently the penetration was checked on that face of the treated specimens.

Specimens *d, e* and *f* are *Pterocarpus macrocarpus* (Burman Padauk), *Pinus longifolia* (Chir) and *Shorea robusta* (Sal), respectively. Specimens *d* and *f* are of hard woods, into which the solution has only penetrated one-fourth inch, but even this is considerably deeper than was the case when treating these species with Creosote oils, while the solution has in parts completely penetrated the Chir specimen *e*.

COST OF TREATMENT.

The following figures giving the cost of treatment are based on the percentages of absorption given in the above table. The cost per gallon of the concentrated solution comes to R16 per 5 gallon drum or 51·2 annas per gallon of 16·28 lbs. weight or 0·19 annas per oz. (concentrated). The solution used was 20 per cent. of concentrated "Atlas" to 80

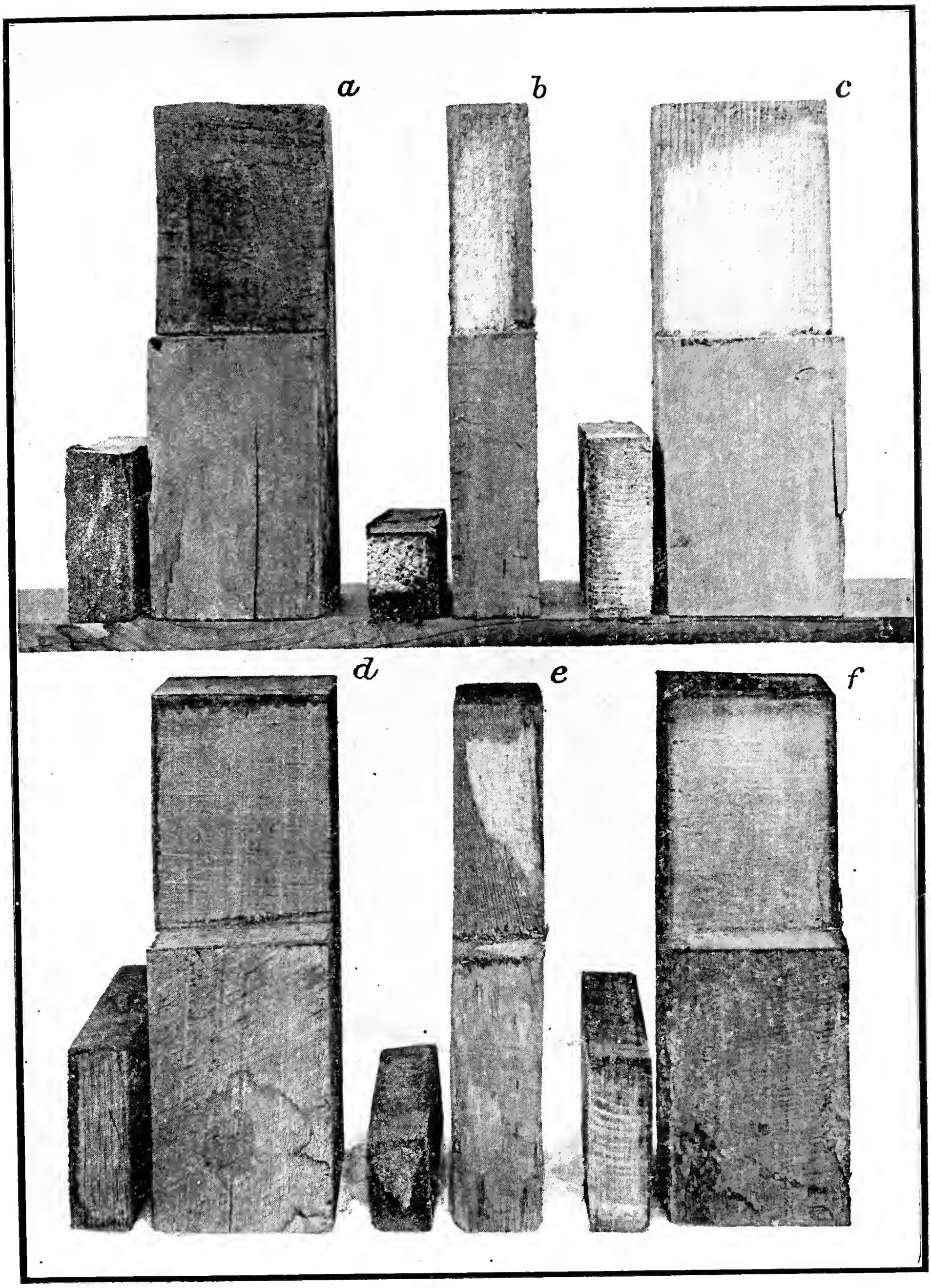


Photo-Mechl. Dept., Thomason College, Roorkee.

Degree of penetration of **Atlas** into the wood of **a** *Boswellia serrata*, **b** *Pinus excelsa*, **c** *Picea Morinda*, **d** *Pterocarpus macrocarpus*, **e** *Pinus longifolia* and **f** *Shorea robusta*, after immersion in this antiseptic.

[To face Plate 74.

per cent. of water, so that the price works out to 0·038 per oz. for the diluted solution. The volume of a B. G. sleeper is taken as 3·3 cubic feet and its superficial area 24·4 square feet.

Species.	Cost of processing.	Cost of solution absorbed by a B. G. sleeper per superficial area in sq. ft.	Cost of solution absorbed per B. G. sleeper per cub. ft.	Total cost of treating a B. G. sleeper based on superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete impregnation.
	anna.	annas.	annas.	annas.	annas.
Boswellia serrata	1	33·5	63·8	34·5	64·8
Pinus longifolia .	1	15·9	45·1	16·9	46·1
Pinus excelsa .	1	19·4	55·2	20·4	56·2
Picea Morinda .	1	7·8	13·6	8·8	14·8
Abies Pindrow .	1	7·5	18·8	8·5	19·8
Pterocarpus macrocarpus.	1	3·0	4·8	4·0	5·8
Bombax malabaricum.	1	14·4	25·0	15·4	26·0
Bauhinia retusa .	1	11·4	18·3	1 24	19·3
Dipterocarpus tuberculatus.	1	3·6	6·3	4·6	7·3
Anogeissus latifolia	1	4·2	10·4	5·2	11·4
Shorea robusta .	1	4·2	7·3	5·2	8·3
Average .	1	11·35	24·43	12·35	25·43

As before stated the firm advocate a 10 per cent. solution instead of 20 per cent. as used in the above experiments, which would halve the cost of treatment.

These figures of cost for *Atlas* must be treated in the same way as those worked out for *Carbolineum* and *Jodelite,* namely, with extreme caution, as only figures based on work carried out on a large scale can be relied upon. On the other hand they are instructive, for they show, as do the figures in the previous sets of experiments, that the cost of treating soft woods is excessive, while the cost of treating the harder woods, which come into the category of possible sleeper timbers is still within working limits.

PAST RECORDS OF TIMBER TREATED WITH ATLAS SOLUTION.

The solution has been used by Railway Companies in Australia and New Zealand as also in Brazil, and the Agents for Atlas in their prospectus record certificates sent to them by officials and private persons testifying to its value.

The Indian records come chiefly from Managers of Assam Tea Estates, many of whom certify it as effective in keeping off white-ants. Mr. Copeland, Deputy Conservator of Forests, when in charge of the Kamrup Division, stated that he had used Atlas preservative and had absolute faith in it. He used a 25 per cent. solution. Further certificates are given by the Executive Engineers of Dacca, Chattisgarh State, Moradabad and the Resident Engineer, Bombay, Baroda and Central India Railway, all testifying to the efficiency of the preservative.

The following are the results obtained up to date at the Forest Research Institute with the wood specimens treated with a 20 per cent. "A" solution of Atlas and immersion for 24 hours, but which were not coated with coal-tar as is prescribed by the Agents of the "Atlas" solution.

Register No.	Species.	TREATED.			UNTREATED.		
		Date on which laid down.	Date of inspection.	Condition.	Date on which laid down.	Date of inspection.	Condition.
1 and 2	*Boswellia serrata* .	12th June 1909.	17th Aug. 1910.	Showing signs of wet rot though not actually unsound.	12th June 1909.	25th Oct. 1909.	Completely destroyed by white-ants and removed on 25th October 1909.
3 and 4	*Pinus longifolia* .	Do.	Do.	Sound .	Do.	17th Aug. 1910.	White-ants working over the surface.

Register No.	Species.	TREATED.			UNTREATED.		
		Date on which laid down.	Date of inspection.	Condition.	Date on which laid down.	Date of inspection.	Condition.
5 and 6	*Pinus excelsa* .	12th June 1909.	17th Aug. 1910.	Sound .	12th June 1909.	17th Aug. 1910.	Sound.
7 and 8	*Picea Morinda* .	Do.	Do.	Do.	Do.	Do.	Slightly pitted by white-ants.
	Abies Pindrow .	Do.	Do.	Do.	Do.	Do.	......
11 and 12	*Pterocarpus macrocarpus.*	Do.	Do.	Do.	Do.	25th Oct. 1909.	White-ants working over the surface but not yet done any damage.
13 and 14	*Bombax malabaricum.*	Do.	Do.	Do.	Do.	1st Oct. 1909.	Completely eaten in half by white-ants and removed on 1st October 1909.
15 and 16	*Bauhinia retusa* .	Do.	Do.	Do.	Do.	17th Aug. 1910.	Sound.
17 and 18	*Dipterocarpus tuberculatus.*	Do.	Do.	White-ants working over the surface but so far they have done no damage.	Do.	Do.	Slightly pitted by white-ants.
19 and 20	*Anogeissus latifolia*	Do.	Do.	Sound .	Do.	Do.	Sound.
21 and 22	*Odina Wodier* .	Do.	Do.	Do.	Do.	30th Oct. 1909.	Badly damaged by white-ants and removed on 3rd October 1909.
23 and 24	*Shorea robusta* .	Do.	Do.	Do.	Do.	17th Aug. 1910.	Sound.

From the above records it will be seen that with the exception of the specimen of *Boswellia serrata* which shows slight signs of wet rot all the treated woods are in good order. It appears that in the case of

very soft porous woods when placed in moist situations that a coating of tar or paint will be necessary. The untreated woods have fared badly with the exception of Nos. 6, 16, 20 and 24. Three have been completely destroyed necessitating their removal, while five others are under progress of being destroyed.

SUMMARY.

The records of sleeper wood treated with "Atlas" and laid down in India are so meagre that no conclusions can be arrived at as to its value in preserving the timber; it appears, however, to be used with success as a weed-killer and as a disinfectant. Used in 20 per cent. solution it is somewhat expensive; on the other hand, it sinks deep into the timber. Its power to withstand being washed out of the impregnated timber cannot be great if, as pointed out by the Agents, it is necessary to supplement the treatment by applying coal-tar to the timber after impregnation with Atlas; in other words, it must be classed as a "Mixed impregnation" process; it has therefore been grouped under this head in Chapter IV, in which proposals for carrying out future experiments are made.

(7) SOLIGNUM.

SOLIGNUM.

A solution known on the market as "Solignum"* is a patent wood preservative, the exact constitution of which is not known but which probably contains a fair percentage of the heavy oils of Creosote. It is coloured with certain pigments and can be procured in various shades of brown, green, and red. It is used for preserving wood, as a disinfectant, and as a water-proof for stone and brick-work.

* The manufacturers of "Solignum" are Messrs. Major & Co., Ltd., Hull, England, and their Indian Agents, Messrs. Cooper & Co., 333, Abdul Rehman Street, Bombay, and 275, Bowbazar Street, Calcutta. It is sold in three shades of brown and three of green and also in purple-red. The price varies from R15 to R18 per 5 gallon drum according to colour, but if ordered in large quantities the price will be considerably reduced.

METHOD OF TREATMENT.

In the prospectus issued by the Company they state that the solution should be applied with a brush, one or two coats being necessary, either cold or when climatic conditions are unfavourable after being heated to 160°-180° F. It is further stated that Solignum has a tendency to work downwards, so that it is advisable to place the prepared ends of wood that are going into the ground upwards until dry.

When the treated wood is to be varnished it should be allowed to dry thoroughly, this sometimes takes considerable time. A special solution is prepared by the Company, for use in doors, which has the power of drying quicker than the ordinary solution.

ABSORPTION OF THE SOLUTION BY INDIAN TIMBERS.

As the timber to be treated is not immersed in the solution, but is painted on with a brush, the amount of absorption is less than when the timber is treated by the Open Tank Method.

A record of experiments is published by the Company, which were carried out by the Punjab Public Works Department, by which 25 Kail wood (*Pinus excelsa*) battens, 9′-0″ × $6\frac{1}{4}$″ × 3″ (353 square feet) were treated with hot Solignum and with the—

First coat 96 oz.=0·60 gallons were used, and with the
Second „ 56 oz.=0·35 „ „ „

TOTAL=0·95 gallons.

One gallon will therefore cover 372 square feet when two coats of the solution are given to this conifer timber. It was also found that one gallon covered 586 cubic feet if only one coating were given to the wood.

Similar experiments to those carried out with *Avenarius Carbolineum, Jodelite* and *Atlas* solutions were made with Solignum, at the Forest Research Institute. In this case one coating of the hot solution was applied to the timber with a brush; the amount of the fluid taken up by the various species is given below. As by applying the solution with a

brush the preparation could in no case penetrate to the centre of the timber, the calculations in this case are based on superficial area only and not by volume :—

Register No.	Species.	Superficial area of piece treated.	Weight of specimen before treatment.	Weight of specimen after treatment.	Weight of solution taken up.	Amount required per sq. ft.
		sq. ft.	lbs. oz.	lbs. oz.	lbs. oz.	oz.
1	*Boswellia serrata*	1·055	0 15	1 3	0 4	3·79
3	*Pinus longifolia*	0·722	1 7	1 8	0 1	1·39
5	*Pinus excelsa* .	0·722	1 0	1 1	0 1	1·39
7	*Picea Morinda* .	·722	1 12	1 1·25	0 0·25	0·35
9	*Abies Pindrow* .	·722	0 12	0 13·5	0 1·5	2·08
11	*Pterocarpus macrocarpus.*	1·055	2 8	2 8·25	0 0·25	0·24
13	*Bombax malabaricum.*	1·055	1 3	1 5	0 2	1·89
15	*Bauhinia retusa* .	1·055	2 2	2 3	0 1	·95
17	*Dipterocarpus tuberculatus.*	1·055	1 14	1 14·5	0 0·5	0·47
19	*Anogeissus latifolia.*	1·336	3 13	3 14	0 1	0·75
21	*Odina Wodier* .	1·055	1 6	1 7	0 1	0·95
23	*Shorea robusta* .	1·055	2 13	2 14	0 1	0·95

The amount of absorption is generally considerably less than was the case when timbers of similar species were treated by immersion in the other solutions. The results are without doubt far above what they would be were the work to be done on a large scale, so that the above figures are of no real value except to show comparisons of absorption. All the softer timbers with the exception of No. 7 have absorbed, however, a considerable quantity of the preservative, a not unnatural result,

COST OF TREATMENT.

From the figures quoted above of the experiments carried out in the Punjab by the Public Works Department, the cost of treating *Pinus excelsa* battens worked out as follows :—

0·21 anna per square foot for two coats, corresponding to a cost of 5·12 annas for a B. G. sleeper.

0·105 anna per square foot for one coat, corresponding to a cost of 2·56 annas for a B. G. sleeper.

The cost of treating a B. G. sleeper of the species mentioned in the above table is based on the following data. One gallon of Solignum weighs 10 lbs. 11 oz. or 171 oz. The cost of a gallon of the solution comes to R3 per gallon, therefore the cost of one oz. = 0·28 anna. A B. G. sleeper has a superficial area of 24·4 square feet, and by taking the amount of absorption by the various species as given in the above table we get the following figures :—

Species.	Cost of processing.	Cost of solution required to cover a B. G. sleeper.	Total cost of treating a B. G. sleeper.
	anna.	annas.	annas.
Boswellia serrata	0·25	25·9	26·15
Pinus longifolia	0·25	9·5	9·75
Pinus excelsa	0·25	9·5	9·75
Picea Morinda	0·25	2·4	2·65
Abies Pindrow	0·25	14·2	14·45
Pterocarpus macrocarpus	0·25	1·6	1·85
Bombax malabaricum	0·25	12·9	13·15
Bauhinia retusa	0·25	6·5	6·75
Dipterocarpus tuberculatus	0·25	3·2	3·45
Anogeissus latifolia	0·25	5·1	5·35
Odina Wodier	0·25	6·4	6·65
Shorea robusta	0·25	6·4	6·65
Average	0·25	8·6	8·85

It is probable that the average cost of 8·85 annas for treating a B. G. sleeper is too high, and that the results obtained by the Public Works Department in the Punjab are nearer the mark. As before stated, such figures as are given above are deduced from the treatment of very small specimens of wood, and though the results are very fairly consistent throughout for all the solutions experimented with, the figures must be taken with considerable caution. By referring to the table on page 59 it will be seen that the cost of treating the various timbers with *Avenarius Carbolineum* worked out to approximately the same figure as that for Solignum. The price of the former solution is 0·18 anna per oz. against 0·28 anna per oz. for the latter, while the price of treatment of a B. G. sleeper is approximately the same, which is accounted for by the greater absorption of the cheaper antiseptic.

Past Record with Solignum.

Solignum has been tried by the Ordnance and Military Works Departments and both the respective Directors-General of these two Departments have pronounced it efficacious for the preservation of timber.

The Chief Engineer, Punjab Public Works Department, states that three roofs of a range of servants' quarters collapsed and it was found that the poles which had supported the roof were riddled through and through by white-ants. Two years ago they were re-roofed with mud and reeds resting on "Kail" (*Pinus excelsa*) battens. This type of roof is extremely liable to be attacked by white-ants, but the reeds and battens soaked in Solignum have entirely escaped the ravages of the Termites. He further states that various preservatives have been used but none appear to be so economically convenient and effective in use as "Solignum."

Solignum has been tried at Pusa, and the Imperial Entomologist writes as follows :—

> "Solignum has given the best results of any white-ant preservative on wood that I have yet tested, and was effective in stopping the entrance of white-ants to a *pucca* building in which they were doing damage."

> "It is more effective than any arsenic preparation known to me."

The Chief Engineer, Madras and South Mahratta Railway, in his letter No. E-485-a-1925—9643 of the 28th April 1910, to the address of the Forest Economist, states that "some timber pieces were treated with Solignum which is a preparation for preserving wood from the ravages of white-ants and tried in a small white-ant hill itself. None of the pieces have been touched by white-ants. It was very satisfactory."

Twelve species of timber treated with a hot solution and applied with a brush, were laid down on the 6th September 1909; their condition up to the date of inspection was as follows:—

Register No.	Species.	TREATED.		UNTREATED.	
		Laid down on	Condition on 18th August 1910.	Laid down on	Condition.
1 & 2	*Boswellia serrata* .	6th Sept. 1909.	Sound .	6th Sept. 1909.	Destroyed by white-ants and removed on 11th January 1910.
3 & 4	*Pinus longifolia* .	Do.	Do. .	Do.	Sound, 18th August 1910.
5 & 6	*Pinus excelsa* .	Do.	Do. .	Do.	Ditto.
7 & 8	*Picea Morinda* .	Do.	Do. .	Do.	Attacked by white-ants, 18th August 1910.
9 & 10	*Abies Pindrow* .	Do.	Do. .	Do.	Attacked by white-ants and removed on 15th June 1910.
11 & 12	*Pterocarpus macrocarpus*.	Do.	Do. .	Do.	Sound, 18th August 1910.
13 & 14	*Bombax malabaricum*.	Do.	Do. .	Do.	Attacked by white-ants and removed on 30th October 1909.
15 & 16	*Bauhinia retusa* .	Do.	Do. .	Do.	Badly attacked by white-ants, 18th August 1910.

Register No.	Species.	TREATED.		UNTREATED	
		Laid down on	Condition on 18th August 1910.	Laid down on	Condition.
17 & 18	*Dipterocarpus tuberculatus.*	6th Sept. 1909.	Sound .	6th Sept. 1909.	Sound, 18th August 1910.
19 & 20	*Anogeissus latifolia.*	Do.	Do. .	Do.	White-ants working over the surface, 18th August 1910.
21 & 22	*Odina Wodier* .	Do.	Do. .	Do.	Destroyed by white-ants and removed on 11th January 1910.
23 & 24	*Shorea robusta* .	Do.	Do. .	Do.	Sound, 18th August 1910.

The above records are satisfactory so far, though the tests have only being in progress for a year. The untreated timbers have on the whole been damaged to a greater extent than similar pieces put in the ground in conjunction with experiments carried out with other antiseptic solutions.

Plate IX, specimens *a* and *b* illustrate an untreated and a treated pieces of *Boswellia serrata* timber after being placed upright in the ground for four months, and specimens *c* and *d* of untreated and treated *Bombax malabaricum* timber after being in the ground for seven weeks.

SUMMARY.

This solution differs from other antiseptic fluids of the same category, in that it combines colouring matter with antiseptics and is therefore more suitable for indoor work. On the other hand, the depth to which the solution penetrates when applied with a brush, is not so great as in the case of immersion. As regards cost of treatment it compares favourably with other similar patent solutions.

Photo-Mechl. Dept., Thomason College, Roorkee.

Result of white-ant attacks on untreated pieces **a** and **c** of *Boswellia serrata* and *Bombax malabaricum* respectively as compared with the pieces **b** and **d** treated with **Solignum,** which remained unattacked.

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(8) GREEN OIL.

GREEN OIL.

Green Oil* is also a product of Creosote, and used in the same way as the Carbolineum oils, namely, by immersion of the timber in a hot solution for 10 to 15 minutes or more, according to the density and dimensions of the timber to be treated.

ABSORPTION OF THE SOLUTION BY INDIAN TIMBERS.

Pieces of timber of the same species as those before mentioned were immersed for 10 minutes in "Green oil," heated to a little below boiling point. The amount taken up per superficial area of the treated piece and when calculated according to its volume was as follows:—

Register No.	Species.	Superficial area of piece treated.	Volume of piece treated.	Weight of specimen before treatment.	Weight of specimen after treatment.	Weight of solution absorbed.	Absorption per superficial area in sq. ft.	Absorption per cub. ft.
		sq. ft.	cub. ft.	lbs. oz.	lbs. oz.	lbs. oz	oz.	oz.
1	*Boswellia serrata.*	1·06	0·04	1 8	2 1·5	0 9·5	8·96	237·5
3	*Pinus longifolia.*	1·06	0·04	1 12	1 14·5	0 2·5	2·36	62·5
5	*Pinus excelsa*	1·06	0·04	1 0	1 5	0 5	4·72	125·0
7	*Picea Morinda*	1·06	0·04	1 0	1 1	0 1	0·94	25·0
9	*Abies Pindrow*	1·06	0·04	1 0	1 3	0 3	2·83	75·0
11	*Pterocarpus macrocarpus.*	1·06	0·04	2 3	2 3·5	0 5	0·47	12·5
13	*Bombax malabaricum.*	1·06	0·04	0 12	1 0	0 4	3·77	100·0
15	*Bauhinia retusa*	1·06	0·04	2 5	2 6	0 1	0·94	25·5
17	*Dipterocarpus tuberculatus.*	1·06	0·04	1 14·5	2 0	0 1·5	1·42	37·5
19	*Anogeissus latifolia.*	1·06	0·04	2 8	2 9·5	0 1·5	1·42	37·5
21	*Odina Wodier*	1·06	0·04	2 3	2 4	0 1	0·94	25·0
23	*Shorea robusta*	1·06	0·04	2 3	2 4	0 1	0·94	25·0

* Procurable from Burt, Boulton, Haywood, Limited, 54 Rue Caumatin, (ix), Paris, and also from their Agents in London and Riga. Cost *f. o. b.* Antwerp in parcels of 2 tons 7½*s.* per gallon and in 10 ton consignments at 6*s.* per gallon. Freight to Karachi about 25*s.* per ton.

As compared with similar oils such as *Carbolineum* and *Jodelite,* the penetrating power of *Green oil* is greater, while the oil is considerably cheaper. In this case, as in former experiments, the amount absorbed by all the softer species, with the exception of *Picea Morinda,* was excessive.

Cost of Treatment.

The cost of treatment of a B. G. sleeper is based on the percentage of absorption given in the above table. The superficial measurement of a B. G. sleeper is taken as 24·4 square feet and its volume as 3·3 cubic feet. The cost of the solution, if bought in parcels of not less than 10 tons, is 6 annas per gallon *f. o. b.* Hamburg, while the freight per gallon to Karachi comes to 1·3 annas. One gallon weighs 9·6 lbs., therefore cost per oz. comes to 0·047 anna.

Species.	Cost of processing.	Cost of solution absorbed by a B. G. sleeper per superficial area in sq. ft.	Cost of solution absorbed by a B. G. sleeper per cub. ft.	Total cost of treating a B. G. sleeper based on superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete penetration.
	anna.	annas.	annas.	annas.	annas.
Boswellia serrata .	1	10·30	36·83	11·30	37·83
Pinus longifolia .	1	2·70	9·70	3·70	10·70
Pinus excelsa .	1	5·41	19·40	6·41	20·40
Picea Morinda .	1	1·07	3·90	2·07	4·90
Abies Pindrow .	1	3·24	11·33	4·24	12·33
Pterocarpus macrocarpus.	1	0·53	1·93	1·53	2·93
Bombax malabaricum.	1	3·32	15·50	4·32	16·50
Bauhinia retusa .	1	0·50	3·90	1·50	4·90
Dipterocarpus tuberculatus.	1	1·62	5·81	2·62	6·81
Anogeissus latifolia.	1	1·62	5·81	2·62	6·81
Odina Wodier .	1	1·07	3·90	2·07	4·90
Shorea robusta	1	1·07	3·90	2·07	4·90
Average .	1	2·70	10·16	3·70	11·16

PAST RECORDS OF TIMBER TREATED WITH GREEN OIL.

There are no Indian records available as to the value of this antiseptic when applied to Indian timbers, while the records available from Europe are also scanty. M. Henry, of the National Forest School of Nancy, quotes a case of spruce timber, painted over with Green oil and placed in the ground, having lasted 17 years. The surface exposed to the west was more corroded than that facing east, though the former was by no means destroyed.

The Engineer, Mr. Dubois, is now experimenting with treated sleepers on the Toul line; the results, however, are not yet available.

SUMMARY.

The necessity of considering Green oil as a possible antiseptic lies in the fact that it is cheap, as also that it contains heavy creosote oils, and should therefore be a good timber preservative. Definite proposals as to the lines on which further experiments with Green oil are made in Chapter IV.

(9) MICROSOL.

MICROSOL.

Microsol* is an antiseptic solution, of pasty green appearance, soluble in water and according to an analysis made by Professor Arth of the Institute of Chemistry at Nancy, and quoted by M. Henry in his "Préservation des Bois," the solution contains the following ingredients :—Sulphate of copper 70 per cent. in crystalline and powdered form, sulphate of soda, sulphate of lime, small traces of free silicate, and a copper-salt of sulpho-phenol, probably a product obtained from the dry distillation of wood.

The treatment of timber with this antiseptic is by the Open Tank Method, by immersion or by applying the solution with a brush. The strength of the solution used, when mixed with water, varies from 2 per cent. to 4 per cent.; if timber is to be exposed to adverse climatic influences, a solution of at least 4 per cent. is necessary and the period of immersion must be at least 24 hours.

* Microsol is procurable from A. Freitag & Co., Fabrique de Peinture, 155 Rue du Faubourg—Saint Dénis, Paris, France, and from Rosenzweig and Baumann, Cassel, Germany.

PAST REECORDS OF TIMBER TREATED WITH MICROSOL.

The value of this antiseptic, under Indian conditions, is not known. The solution contains a high percentage of sulphate of copper, a salt that was formerly much employed in Europe for the antiseptic treatment of timber. As before pointed out, this salt is liable to be washed out of the timber by heavy rains, and for this reason it has been largely supplanted by other antiseptics. Microsol has, however, been given a fair trial in Europe and the results recorded are favourable. This may possibly be due to the presence of gypsum which being insoluble in water, forms a coat over the cell-walls and retards the action of the rain on the soluble copper sulphate.

M. Henry, in his treatise on the antiseptic treatment of timber above referred to, explains at length his experiments carried out with Microsol, and his photographic plates illustrating treated and untreated timber, which had been utilised as mining-props and also used as posts in the open, during a period of three years, clearly show the value of this antiseptic.

In 1904, the Research Station of Mariabrunn carried out experiments with Microsol known on the market as "H. de 1903." and procured from Eduard Lutz & Co., of Vienna. The experiments show that a 1·5 per cent. solution was quite sufficient to protect the treated coniferous timbers from the attack of *Merulius* and other fungi.

No experiments have been carried out by the Forest Department in India with this solution, but it is proposed to do so shortly.

(10) BÉLLIT EINFACHFLOUR AND DOPPEL FLOUR.

BÉLLIT.

"Béllit"* is a patent antiseptic solution consisting of Sodium-fluoride 80 per cent, Dinitro-phenol 12·5 per cent. and Aniline 6·5 per cent. It s soluble in water, a 1 in 44 solution being used, or 2·25 kilos. to 100 litres of water. The solution should be heated to nearly boiling point, and the timber allowed to remain in the fluid as it cools down for a period varying from 24 to 48 hours, according to the density and dimensions of the timber to be treated. The difference between Einfach and

* Béllit is obtained from the Oesterrichischer Verein für Chemische ünd Metallurgiscke Producten, Aussig. A/E Austria, also from the Chemical Factory, Griesheim, Frankfurt, A/M, Germany.

Doppel flour consists, simply in the varying proportions of Sodium-fluoride to Dinitro-phenolanilin, thus Einfachflour consists of 1 part of sodium-fluoride and 0·25 parts of Dinitro-phenolanilin, and Doppel-flour consists of 2 parts of sodium-fluoride to 0·25 parts of Dinitro-phenolanilin.

ABSORPTION OF THE SOLUTION BY INDIAN TIMBERS.

Experiments have been recently carried out in order to ascertain the amount of the solution taken up by various Indian timbers. The specimens were treated with Béllit Doppel-flour, by immersion in a solution of 1 in 44, heated to nearly boiling point and the timber allowed to remain in the fluid while it cooled down for 48 hours. The amount of absorption by the various species was as follows :—

Register No.	Species.	Superficial area of pieces treated.	Volume of piece treated.	Weight of specimen before treatment.		Weight of specimen after treatment.		Weight of solution absorbed.		Absorption per sq. ft.	Absorption per cub. ft.
		sq. ft.	c. ft.	lbs.	oz.	lbs.	oz.	lbs.	oz.	oz.	oz.
1	*Boswellia serrata.*	1·06	0·04	1	7	2	0	0	9	8·49	225
3	*Pinus longifolia.*	1·06	0·04	1	8	2	8	1	0	15·09	400
5	*Pinus excelsa*	0·69	0·027	0	14	1	2	0	4	5·79	148
7	*Picea Morinda*	1·06	0·04	1	3	1	11	0	8	7·55	200
9	*Abies Pindrow*	1·06	0·04	1	1	1	15	0	14	13·21	350
11	*Pterocarpus macrocarpus.*	1·06	0·04	2	4	2	6	0	2	1·89	50
13	*Bombax malabaricum.*	1·06	0·04	1	0	1	12	0	12	11·32	300
15	*Bauhinia retusa.*	1·06	0·04	2	5	2	13	0	8	7·55	200
17	*Dipterocarpus tuberculatus.*	1·06	0·04	2	4	2	6·5	0	2·5	2·36	62·5
19	*Anogeissus latifolia.*	1·06	0·04	2	6	2	12·5	0	6·5	6·13	162·5
21	*Odina Wodier*	1·06	0·04	1	9	2	1	0	8	7·55	200
23	*Shorea robusta*	1·06	0·04	2	4	2	6·5	0	2·5	2·36	62·5

The excessive absorption of *Béllit* by the various specimens very much resembles what took place when similar species were treated with an *Atlas* solution for which the water in both solutions is largely responsible, as also the prolonged period of immersion. The timber on drying

loses the water and so practically regains its normal weight, while the antiseptic chemicals remain in the tissue. The result of this is naturally deeper impregnation than is the case with the Creosote oils, a point in favour of such salts.

COST OF TREATMENT.

Béllit is sold in Austria, in a powdered form at R1-4 per kilo or 2·2 lbs., the cost of exporting it to India may be put at R28 per ton. The solution used is 1 in 44 or taking a gallon as 10 lbs., the cost of a gallon of the dilute solution comes to 2·1 annas, or ·013 anna per oz. A B. G. sleeper contains 3·3 cubic feet or 24·4 superficial square feet; basing our calculations on the amount of absorption as given in the above table, the cost of impregnating a B. G. sleeper works out as follows :—

Species.	Cost of processing.	Cost of solution absorbed by a B. G. sleeper, per superficial area, in sq. ft.	Cost of solution absorbed by a B. G. sleeper, per cub. ft.	Total cost of treating a B. G. sleeper, based on superficial absorption.	Total cost of treating a B. G. sleeper based on the assumption of complete impregnation.
	anna.	annas.	annas.	annas.	annas.
Boswellia serrata .	1	2·7	9·7	3·7	10·7
Pinus longifolia .	1	4·8	17·2	5·8	18·2
Pinus excelsa .	1	1·8	6·4	2·8	7·4
Picea Morinda .	1	2·4	8·6	3·4	9·6
Abies Pindrow .	1	4·2	15·0	5·2	16·0
Pterocarpus macrocarpus.	1	0·6	2·1	1·6	3·9
Bombax malabaricum.	1	3·6	12·9	4·6	13·9
Bauhinia retusa .	1	2·4	8·6	3·4	9·6
Dipterocarpus tuberculatus.	1	0·7	2·7	1·7	3·7
Anogeissus latifolia.	1	1·9	7·0	2·9	8·0
Odina Wodier .	1	2·4	8·6	3·4	9·6
Shorea robusta .	1	0·7	2·7	1·7	3·7
Average .	1	2·4	8·5	3·4	9·5

The cost of treating B. G. sleepers with Béllit is low according to the above figures which closely resemble those given on page 29, Chapter II, for the treatment of sleepers with Chloride of Zinc, while the cost is hardly one-fourth that of treating timber with Creosote oils.

PAST RECORDS.

No records are available for India, as the above-mentioned pieces of treated timber have only been in the ground a month, nor are any reliable data available from Europe, as the process is a comparatively new one. It is, however, very highly recommended by Hauptmann B. Malenković, whose opinion in such matters deserves every consideration.

SUMMARY.

There can be no doubt that this method of treating timber is extremely cheap. Time alone can prove its value, the fear being that the salt may be washed out of the timber in spite of the small quantities of Phenol which it contains. Provided the salt is a good antiseptic, its use together with small quantities of the heavier oils of creosote which together would not make the cost of treatment excessive, might well prove of great value.

(II) CRÉSOL-CALCIUM.

CRÉSOL-CALCIUM.

Crésol-Calcium [1] is a new antiseptic solution the composition of which has been fully discussed on page 33, Chapter II. It can be used for treating timber by the Open Tank Method, but is more commonly forced into the timber under pressure. A five per cent. solution is recommended by the inventors for impregnation under pressure, but if used in the Open Tank process a stronger solution is necessary. The Company in their prospectus compare the cost of treating timber with

[1] Crésol-Calcium is procurable from Blagden Waugh & Co., 50-51, Lime Street, London, E. C., England.

Creosote by the old method, by the Rüping process, and with Crésol-Calcium salt, which they state works out as follows :—

> Taking for example a sleeper of 3 cubic feet, the cost of impregnation according to the old method, where 3 gallons of Creosote were used, comes to 9*d*. per sleeper ; in the case where 1 to 2 gallons are forced in according to the Rüping process, the cost works out to 3·6*d*. and with Crésol-Calcium it comes to 1·4*d*. per sleeper.

PAST RECORDS OF TIMBER WITH CRÉSOL-CALCIUM.

No experiments have been so far carried out in India with *Crésol-Calcium*. The substance is new on the market, so that no conclusive results are as yet available from Europe. The *Indian Trade Journal* of the 7th April 1910 states that " the Swedish State Railways will already this year impregnate with Crésol-Calcium half the quantity of their sleepers, annually treated." They also say that experiments are to be made by the United States Forest Department with Crésol-Calcium.

SUMMARY.

The employment of such a salt for Indian use remains to be proved and unless the boiling point of the tar-acids of which it is largely composed, (other than Phenol), is materially raised by their combination with milk of lime, good results cannot be expected.

(12) CRÉSOYLE.

Crésoyle[1] is another of the patent solutions which can be used by the Open Tank Method. It is also composed of the heavier oils of coal-tar, with a density of 1·05. It can be used in the same way as Créosote by pneumatic injection, or by immersion of the timber or as paint.

It has been extensively used by the Royal Engineers, and Railway Administrations in Belgium, with satisfactory results. So far no records are to hand of experiments carried out with Crésoyle in India.

[1] Crésoyle is obtained from Messrs. Gaston Mertens, Seneffe, Belgium. It costs 50 centimes a Kilo or 2·27 annas per lb. = R1-7-9 per gallon in Belgium.

(13) OTHER ANTISEPTICS.

Many other antiseptic solutions are on the market; as little is as yet known of their value under Indian conditions they are here only mentioned for future reference.

ZINC-CHLORIDE AND SODIUM-FLUORIDE.

(*a*) Zinc-chloride [1] and sodium-fluoride mixed in equal quantities is strongly recommended by Hauptmann B. Malenković. The strength of the solution necessary is 3·5 per cent. ZnCl and 3·5 per cent. NaF., and a period of immersion of 8 days is advocated. It is an extremely cheap process, and if it affords protection to timber as stated, it should be of value in India.

BÉLLITOL.

(*b*) Béllitol [2] is a 2 per cent. solution of Dinitro-benzol and mineral oil (boiling point 300°C.). It is used in the same way as Béllit.

HYLINIT.

(*c*) Hylinit [3] is one of the many antiseptic solutions on the market; its composition is not known, nor are any records available of its use in India. The strength of the solution recommended, when the timber is treated by immersion, is 5 per cent., the period of soaking being 24 hours.

ANTHROL.

(*d*) Anthrol [4] is a patent antiseptic solution used for the preservation of timber, masonry work, leather, ropes, canvas, etc. It can be used

[1] Sodium-fluoride is obtainable from the Oesterreichischer Verein für Chemische und Metallurgische Producten, Aussig A/E Austria. Zinc-chloride can be obtained from any wholesale chemist in India.

[2] Béllitol can be obtained from the Chemical Factory at Griesheim, Frankfurt A/M, Germany, while the oil from Burma will answer the purpose of mineral oil.

[3] "Hylinit" is obtained from the Cartvale Chemical Co., Ltd., Paisley, England. It costs £3-5-0 per cwt. in lots of 10 cwt. and upwards, *c. i. f.*, U. K. ports.

[4] "Anthrol" is obtained from the Anthrol Co., Strathclyde Works, Kinning Park, Glasgow. Cost £0-1-6 per gallon, *f. o. b.*, Glasgow, if taken in 40 gallon casks.

as paint or by the immersion process. The prospectus advocates heating the solution. No records are available as to its use in India.

OTHERS.

(*e*) Afral.[1]
(*f*) Antiformine.[2]
(*g*) Antigermine.[3]
(*h*) Lysol,[4] etc., etc.

[1] "Afral" is procured from the Chemical Factory at Heyden, Dresden, Germany.
[2] "Antiformine" is obtained from Messrs. Oscar Kühn of Berlin.
[3] "Antigermine" is obtained from Fr., Bayer & Co., Elberfeld, Germany.
[4] "Lysol" is obtained from the Société Française of Lysol, France.

CHAPTER IV.

Proposals as to the lines on which the future investigation into the antiseptic treatment of sleeper-woods should be carried out.

CHAPTER IV.

PROPOSALS AS TO THE LINES ON WHICH THE FUTURE INVESTIGATION INTO THE ANTISEPTIC TREATMENT OF SLEEPER-WOODS SHOULD BE CARRIED OUT.

(1) General Remarks.

PROBABLE CAUSES OF FAILURE TO INTRODUCE WOOD-ANTISEPTICS INTO MORE GENERAL USE IN INDIA.

Before making definite proposals as to the lines on which further experiments should be carried out with antiseptics, it is necessary to briefly review the causes of failure in the past. In Chapter I it has been stated that during the fifties and sixties of the last century, several large impregnating plants were erected by the different railway companies, by which either creosote, copper sulphate or chloride of zinc was forced into the timber, and later the Bombay, Baroda and Central India Railway experimented with Haskinized sleepers, while many experiments on a smaller scale with timbers treated in different ways have from time to time been carried out with varying success.

With the exception of the creosoted Red Pine sleeper imported from Europe by a few railway companies and the application of tar by others, the method of preserving sleeper-woods by the help of antiseptics is not in general use in India. It is true that timber used for other purposes in India is treated with the various patent antiseptic solutions now on the market, but their use is not nearly so general as is the case in European countries.

The reason for this backward state of affairs would have been more easy to explain 50 years ago than it is to-day. The quantity of sleeper-wood then required was not so great as it is at the present time nor were the prices of timber so high, so that the question not being at that time of primary importance, the first attempt to obtain satisfactory results, which were not successful, were not persevered in.

Another reason for discontinuing the work and closing down the large plants erected during the middle of the last century was the excessive cost of treating the timber.

Another cause to which former failure is attributed was the imperfect knowledge of the various methods by which timber could then be

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treated, and to the fact that the lines on which the work was carried out followed too closely European methods without adapting them sufficiently to Indian conditions and the varying quality of Indian timbers.

Present Position of Affairs.

At the present time there can be no doubt that the possible supply of sleepers is insufficient to meet the demand. As a proof of this assertion it may be stated that iron sleepers are now being used and that very large numbers of Jarrah and other Australian woods, as also creosoted Red Pine, are being annually imported into India, while the price of the better Indian sleeper timbers is ever increasing. The output of good Indian sleepers cannot be expected to increase very materially in the near future in any case not until the forests which had been so heavily overworked when taken over by the Forest Department have had time to recover; this is in most cases a very slow process.

The only way to make up the shortage appears to be either to use iron sleepers or to extend the use of imported sleepers or by applying antiseptic treatment to our better auxiliary species of timber in order to render them suitable for sleepers.

The former difficulties which rendered unsuccessful the treatment of the various species of timber with different antiseptics have now to a great measure disappeared. The most important factor against successful treatment was its excessive cost. At the time when the first attempts were made to impregnate sleepers in India, their market value was hardly two-thirds of what it is now, so that the margin of cost of treatment was very small as compared to what it is to-day. Again, the various methods of processing timber have been much improved in this respect, and the attention of specialists has been given as much to the question of reducing the cost of treatment as to the possibility of finding new methods by which timber can be treated. The result of these enquiries has been the introduction of the "Rüping process" by which the quantity of creosote it is necessary to inject into the timber has been reduced by 35 per cent. to 40 per cent.; the very extensive use of the "Open Tank Method," by which the cost of plant is reduced to a nominal figure; and "Mixed Impregnation" by which timber is treated with a cheap salt and the salt protected by a small quantity of a somewhat expensive non-volatile insoluble oil, the combination of the two substances reducing the price of treatment as compared with the cost of processing with the oil only.

Owing to the altered conditions under which it is now possible to work, it is considered that provided the experiments are carried out upon sound economic and scientific lines, the chances of success are considerably greater than they were in the past.

THE POINT TO WHICH THE EXPERIMENTS HAVE AT PRESENT BEEN CARRIED.

As has been stated elsewhere the experiments at present being carried out by the Forest Department as to the possibility of treating timber with an antiseptic in order to preserve it from decay or destruction by white-ants come under two heads. The first are laboratory experiments, carried out on a small scale, which consist in treating the various pieces of timbers with the better known antiseptic solutions, and then placing them in the ground and keeping them under observation. These experiments, together with those relating to absorption, cost, strength and durability have been in progress about eighteen months.

Under the second head come the experiments carried out on a more extensive scale in the course of which a large number of sleepers are treated by a process, the value of which has been established by previous records and laboratory experiments, and handing over the sleepers after treatment to the Railway Authorities by whom they are placed on an open line and periodically inspected. So far arrangements have been made to Powellise 5,000 sleepers of *Dipterocarpus tuberculatus,* the "In" wood of Burma, *Dipterocarpus alatus, Pinus excelsa* or Kail wood, *Pinus longifolia* or Chir wood, and *Terminalia tomentosa* or Sain wood. It is hoped that these sleepers will be ready to hand over to the Railway authorities by April 1911.

Another scheme has been submitted by which it is proposed to treat 2,500 sleepers of the same five species above mentioned by the Open Tank Method with *Avenarius Carbolineum* oil and after treatment to place them in open lines so as to ascertain their behaviour under varying conditions of climate and mechanical strain.*

(2) Proposals as to Future Experiments.

While formulating proposals as to future experiments it is necessary to consider the three most important factors which govern the possibilities

* NOTE.—Since writing this paragraph, this experiment has been successfully launched, and a third set of experiments is under consideration by which 1,500 sleepers will be treated with Green Oil and Chloride of Zinc, by the mixed Impregnation Method.

of success, which are (i) the species of timber with which to experiment, (ii) the cost of treatment, and (iii) the antiseptics with which to work. It will be necessary to deal with each head separately.

(*a*) SPECIES OF TIMBER.

Species of Timber with which it is proposed to experiment.

On page 11, section 3, Chapter I, is given a list of timbers, divided into three classes, according to their value as possible sleeper-woods, while the remaining portion of that section is devoted to their relative merits. It is proposed that future experiments, with possibly slight modifications, shall be confined to these timbers, and that those in class I shall be dealt with before those in class II, etc.

(*b*) COST OF TREATMENT.

Before it is possible to decide on the antiseptics with which experiments should be made or by what process the timber should be treated, it is necessary to briefly review the figures of cost of treatment. As we have many possible methods of treatment to consider, which have been fully discussed in the previous chapters, it will simplify matters to tabulate the figures deduced from previous experiments and actual working so as to form a fair conception of their relative merits. The following figures of cost of treating a B. G. sleeper are taken from the body of this report:—

Process.	Species.	Total cost of treating per B. G. sleeper.	REMARKS.
		R a. p	
CREOSOTING Old method (taking creosote in India at 7 annas per gallon).	(1) Hard woods taking up 3 lbs. of oil per cubic foot.	0 8 5	Estimates based on the present price of Creosote in India.
	(2) Moderately hard wood taking up 6 lbs. of oil per cubic foot.	0 15 4	
	(3) Soft woods, taking up 10 lbs. of oil per cubic foot.	1 8 7	

Process.	Species.	Total cost of treating per B. G. sleeper.	REMARKS.
		R a. p.	
CREOSOTING Old method (taking creosote in India at 7 annas per gallon)—*contd.*	*Pinus longifolia* .	2 2 0	Actual cost of treatment at Aligarh in 1870.
Ditto . .	*Ditto* . .	0 14 8	Actual cost of treatment on the Light Railway, N.-W. P., in 1874.
RÜPING PROCESS, WITH CREOSOTE.	(1) Hard woods ..	0 4 2	The figures are arrived at by taking the absorption as half that in the case of the old method of creosoting.
	(2) Moderately hard woods.	0 7 8	
	(3) Soft woods .	0 12 3	
HASKIN PROCESS .	Hard woods . .	0 13 2	Prices charged by the Company in England for treating timber.
	Soft woods . .	0 8 2	
Ditto . .	Moderately hard wood	0 2 0	Exclusive of royalty. The figure is taken from an estimate put up by Dr. Gibson in 1898 for working under Indian conditions.
BOUCHERIE PROCESS or copper-sulphate impregnation.	Beech and Pine woods	0 4 4	The figures apply to European conditions and are taken from an estimate put up by Dr. Warth in 1878.
BURNETT'S PROCESS or impregnation with chloride of zinc.	Hard woods . .	0 2 0	Estimates based on the present price of chloride of zinc in Calcutta.
	Moderately hard woods	0 2 8	
	Soft woods .	0 3 5	
Ditto . .	Beech	0 2 2	Figures based on cost of treatment in England, quoted by Dr. Warth.
	Oak	0 2 10	

Process.	Species.	Total cost of treating per B. G. sleeper.	Remarks.
		R a. p.	
Crésol-Calcium .	Not known, probably pine woods.	0 1 6	The figure is based on data given by the promoters for treating an English sleeper and worked out for a corresponding B. G. sleeper. This price does not include freight to India of the salt, and royalty charges.
Kyanizing process or impregnation with chloride of mercury.	(1) Hard woods .	0 4 7	These figures are worked out on the present price of corrosive sublimate in Calcutta.
	(2) Moderately hard woods.	0 8 2	
	(3) Soft woods .	0 12 11	
Ditto . .	For all woods by using a 0·66 per cent. solution of salt.	0 3 0	The figure is taken from Dr. Warth's report of 1878. It is probably too low for Indian conditions.
Powellizing process impregnation with a saccharine solution.	Any timber . .	1 0 6*	The present rates charged by the Powell Co. in Bombay are 5 annas per cubic foot.
Ditto . .	Karri timber . .	0 11 4	The figure is based on the cost of treating Karri sleeper in Australia, exclusive of royalty.
Avenarius Carbolineum Oil.	*Pinus excelsa* (Kail).	0 7 7	Results of laboratory experiments, calculated on Indian prices. They are probably somewhat high and would be reduced if work was done on a large scale.
	Pterocarpus macrocarpus (Burman Padauk).	0 5 8	
	Dipterocarpus tuberculatus ("In" wood)— (i) after 1 hour's immersion.	0 3 1	

* Note.—Were the work to be carried out on an extensive scale, the Powellizing Co. think that the cost of treatment could be considerably reduced.

Process.	Species.	Total cost of treating per B. G. sleeper.	Remarks.
		R a. p.	
AVENARIUS CARBOLINEUM OIL—*contd.*	*Dipterocarpus tuberculatus* "In" wood—		Results of laboratory experiments, calculated on Indian prices. They are probably somewhat high and would be reduced if work was done on a large scale.
	(ii) after 2 hours' immersion.	0 9 1	
	(iii) after 3 hours' immersion.	0 17 1	
	Averge cost of treating twelve soft to hard species of timber.	0 8 6	
JODELITE . .	*Pinus excelsa* (Kail)	0 6 7	Ditto.
	Pterocarpus macrocarpus (Burman Padauk).	0 5 0	
	Dipterocarpus tuberculatus ("In" wood).	0 5 0	
	Average cost of treating twelve soft to hard species of timber.	0 10 8	
ATLAS SOLUTION .	*Pinus excelsa* (Kail)	1 4 5	Results of laboratory experiments. In this case the cost of treating soft woods is generally excessive, while the cost of treatment of hard woods is less than in the case of tar oils.
	Pterocarpus macrocarpus (Burman Padauk).	0 4 0	
	Dipterocarpus tuberculatus ("In" wood).	0 4 7	
	Average cost of treating twelve soft to hard species of timber.	0 12 4	

Process.	Species.	Total cost of treating per B. G. sleeper.	Remarks.
		R a. p.	
Solignum . .	*Pinus excelsa* (Kail)	0 11 2	See note against *Avenarius Carbolineum.*
	Pterocarpus macrocarpus (Burman Padauk).	0 2 9	
	Dipterocarpus tuberculatus ("In" wood).	0 4 4	
	Average cost of treating twelve soft to hard species of timber.	0 9 3	
Green Oil . .	*Pinus excelsa* (Kail).	0 6 5	Results of laboratory experiments.
	Pterocarpus macrocarpus (Burman Padauk).	0 1 6	
	Dipterocarpus tuberculatus ("In" wood).	0 2 7	
	Average cost of treating twelve soft to hard species of timber.	0 3 8	
Béllit . . .	*Pinus excelsa* (Kail)	0 2 9	Ditto.
	Pterocarpus macrocarpus (Burman Padauk).	0 1 7	
	Dipterocarpus tuberculatus ("In" wood).	0 1 8	
	Average cost of treating twelve soft to hard species of timber.	0 3 5	

From the above figures it will be seen that, generally speaking, the cost of treatment is high when tar-oils and products therefrom are used, such as *Creosote, Avenarius Carbolineum, Jodelite,* and also for the *Saccharine* process, while the cost of impregnation with the various salts is not expensive; take, for instance, *Chloride of zinc, Copper sulphate,* and *Béllit* (Sodium-fluoride). On the other hand, the value of processes by which an oil is injected or applied is generally greater than is the case when timber is treated with a salt, for the reason that the oils are less volatile and are not so easily removed from the timber by the action of rain. The above points will be taken into consideration in choosing the antiseptic solutions with which further experiments are to be made.

(3) ANTISEPTIC SOLUTION WITH WHICH IT IS PROPOSED TO EXPERIMENT IN FUTURE.

(*a*) IMPREGNATION BY PNEUMATIC INJECTION.

(*1*) *Creosote.*—Creosoting by the old method is not practicable being too expensive. It is proposed to experiment with creosote by the Rüping process. As no Rüping plant exists in India, it will be necessary to send 50 or 100 sleepers of eac of the species mentioned in class I on page 11, Chapter I, to Europe for treatment. If the experiment is a success, further schemes for erecting a Rüping plant in India might be considered.

(*2*) *Haskin process.*—The process is a cheap one, but not altogether applicable to India, though it deserves consideration. The best chances of success are to fulfil to the utmost the conditions on which the whole theory of the process is based. To do this the timber to be treated must contain much sap or oleo-resinous substances, and when treated it should be in a green state. Such a species as *Dipterocarpus tuberculatus* is recommended. The timber will have to be sent to Europe for treatment in the shape of freshly cut logs, to be converted into sleepers on arrival. It will be necessary to send sufficient timber home to produce 100 B. G. sleepers.

(*3*) *Sulphate of copper.*—It is not proposed to make any experiments with this salt at present.

(*4*) *Chloride of zinc.*—This process will be dealt with under "Mixed Impregnation."

(*b*) THE OPEN TANK METHOD.

(1) *Corrosive sublimate or Bichloride of Mercury.*—The process is not to be advocated for India, as the highly poisonous nature of the salt makes it objectionable.

(2) *Powell's process.*—The experiments on a large scale by which 5,000 sleepers are to be treated are already well under way, as are also the laboratory experiments. The subject therefore requires no further remarks.

*(3) *Avenarius Carbolineum.*—The laboratory experiments are well in hand, and a scheme to treat 2,500 sleepers with *Avenarius Carbolineum* oil has been submitted for sanction, and it is hoped that the work of carrying out this experiment will shortly be taken in hand.*

(4) *Jodelite.*—As funds are available, experiments on a large scale are proposed with this oil, to be carried out on the same lines as those with Carbolineum; in the meantime the laboratory experiments will be continued.

(5) *Atlas solution.*—This antiseptic is dealt with under "Mixed impregnation."

(6) *Solignum.*—It is not proposed at present to carry out experiments with Solignum on as large a scale as with Carbolineum and Jodelite, as the solution is more of the nature of a paint and is therefore more suitable for indoor work. As regards its cost, it compares favourably with other similar solutions, but this condition of affairs would most probably no more hold good were the timber to be immersed in the solution, instead of being applied with the brush.

The laboratory experiments will, however, be continued, and if after a reasonable time the timber is found to be preserved from decay by merely painting on the fluid, the advisability of treating large numbers of sleepers as a further experiment may be considered.

(7) *Green Oil and Béllit.*—To be experimented with on a laboratory scale; they are also dealt with under "Mixed impregnation."

(8) *Microsol and Crésol-Calcium.*—To be experimented with on a laboratory scale only at present.

(*c*) "MIXED IMPREGNATION."

The object of the treatment of timber by mixed impregnation is to reduce the cost of the process. This is effected by first treating the

*NOTE.—Since writing the above paragraph the experiment has been successfully launched.

timber with a salt, generally a cheap process, and protecting the salt from being washed out of the timber or volatilizing under excessive temperature by a further treatment with a small quantity of one of the more expensive antiseptic oils.

Proposed various combinations with which to treat timber:—

*1. Zinc chloride and green oil, the timber being immersed in a solution of the former and when dry painted over with the latter.

2. Zinc chloride and Avenarius Carbolineum and to be treated in the same way as No. 1.

3. Béllit and Jodelite to be treated in the same way as No. 1.

4. Atlas and tar to be treated in the same way as No. 1.

5. The experiments with Sodium-fluoride and Zinc chloride are already under way on a laboratory scale and should be continued.

Other antiseptic solutions, such as Crésoyle, Béllitol, Hylinit, Anthrol, Afral, Antiformine, Antigermine, Lysol, etc., will be taken up as opportunity offers.

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*NOTE.—Proposals to treat 1,500 sleepers of five different species by this method are now under consideration.

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Report on the Investigation of Bamboo as Material for Production of Paper-pulp.

By

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INTRODUCTORY.

DURING the past ten years a considerable amount of research and investigation work has been done on the subject of utilisation of bamboo for the manufacture of cellulose, or pulp, for paper-making, principally by Sindall, Richmond (American Bureau of Science, Manila) and myself. To the reports of Messrs. Sindall and Richmond I am indebted for much valuable information and I have, to a large extent, made use of these as guides and foundations for the investigations herein detailed. The results of a considerable number of trials and experiments by pulp and paper-makers have also from time to time been published, but the general impression derived from a review of the whole is one of disappointment at the want of harmony in their conclusions. The one point on which all are agreed is that bamboo yields excellent cellulose, but scarcely any two agree, even approximately, on the yield which has varied from 33 to 50 per cent., on the soda consumption which has been reported as low as 16 and as high as 40 per cent. or on the bleaching powder required which has been quoted at from 9 to 40 per cent. There has also been considerable difference of opinion as to its behaviour under digestion, some experimentalists claiming even and regular digestion throughout the mass, while others assert that the results are irregular

and the pulp invariably spoilt by much hard and imperfectly digested matter. This has naturally given rise to a suspicion in manufacturing circles that bamboo is an unreliable material, variable in its composition and uncertain in yield, quality and cost. With a genus numbering some hundreds of species growing over a wide range of latitude and under widely dissimilar conditions of soil, elevation and climate, it would not be surprising if considerable variation in results were found to really exist, but this investigation has been undertaken in the belief, based on a twelve years' study of the subject, that so far as the leading and predominant species of India and Burma are concerned,—those which exist in quantities sufficient for, and under local conditions permitting of their economical exploitation,—all the serious variations referred to either do not exist or can be eliminated by suitable treatment, and those which remain are of no practical importance.

2. Investigators have hitherto laboured under considerable disadvantages owing to the little that was known of bamboo; of its species and their habitats, of the extent to which certain species dominate others, of the extent to which various species exist in commercial quantities and under exploitable conditions, of the best system of felling looking to the fact that want of proper precautions may result in injury to the clumps and restrict their reproductive powers, of the best age to cut the individual culm, and of the percentage of knots or nodes in each species. The Forest Economist's report, which is now being published, clears up all this ground and establishes definite conclusions upon these points. I have had an opportunity of studying it while it was under preparation, and the course and direction of my own work has been considerably modified in consequence. Had such a report been available ten years ago much misdirected energy would have been saved. To cite but one point :—it has been very naturally supposed that age is a matter of the first importance, and, as shown by Sindall (in his Burma report, 1906), this is not merely a supposition but a fact. Under the methods of treatment hitherto applied considerable weight has been attached to the question of age, and much importance has been assigned to the selection of bamboos based on their age and to the different degrees of treatment deemed necessary for stems of various ages. The Economist's report now makes it clear that all this has been wasted effort, that no selection based on age is possible after the first year's growth, that the proportion of one year old culms to the whole clump is not sufficient to make their separate selection of much value, and that even their distinctive appearance disappears after a few weeks drying; in short, that whether it suits

us or not, in the annual cutting of each species, culms of all ages must be dealt with mixed and as a whole or not at all. The effect of the Economist's report upon my department of the enquiry has therefore been to largely limit its scope, and to direct it into those channels which his careful and systematic investigation into the economic conditions governing the exploitation and growth of bamboo shows to be the most practical.

3. My investigation has therefore been restricted to the five species, *viz., Bambusa arundinacea, B. Tulda, B. polymorpha, Cephalostachyum pergracile* and *Melocanna bambusoides,* found by the Economist to be the ones most worthy of serious attention in the districts he has reported upon, and the chief points to be investigated as ascertained from a careful study of former efforts and results, qualified and limited by the Economist's conclusions, are :—

(*a*) The suitability of the five species mentioned for the manufacture of cellulose at a marketable cost.

(*b*) Whether the fact that culms of all ages must be dealt with mixed and as a whole constitutes a serious difficulty.

(*c*) Whether the nodes must be cut out and rejected.

(*d*) Whether the differences between species will permit of their being mixed during treatment.

It will be convenient to divide the report into sections as follows :—

A.—Physical.
B.—Analytical.
C.—Digestions.
D.—Microscopical.
E.—General conclusions.

4. The following definitions and abbreviations will be made use of :—

N.A.D., or normal air dry=containing 90 per cent. of absolutely dry substance and 10 per cent. of water.

NaOH=*Sodium hydroxide* in its commercial form as Caustic Soda of 76 per cent. strength.

Na_2S=*Sodium Sulphide.*

B. P.=Bleaching powder (*calcium hypochlorite*) containing 35 per cent. available chlorine.

Tw. = Twaddel's hydrometer for measuring density of liquids. Each degree corresponds to 5 degs. of specific gravity above that of water taken as 1,000. Thus 7 degrees Tw. means 1,035 sp. gr.

Temperatures are quoted in terms of the centigrade thermometer: *pressures* in pound per square inch above normal atmospheric pressure.

Digester results are given in per cent. of N. A. D. pulp from N. A. D. raw material : *B.P.* consumed, in per cent. on N. A. D. unbleached pulp except when otherwise stated. *Standard white* means the highest degree of whiteness to which the pulp can be bleached without incurring the risk of serious oxidation and loss of fibre. It may be described as a brilliant white, or full bleach, and is good enough for the highest grades of printing and writing paper. *Unbleachable* is used throughout in the sense of unbleachable within economic limits of cost.

SECTION A.

Physical.

Structural.

5. In structure, bamboo presents several features which markedly differentiate it from any of the raw materials now in use. It is porous, thereby differing from coniferous wood; its pores* run vertically in close, straight and regular series throughout the culm, (see paragraph 34). They form capillary tubes, open throughout their whole length, which in the green culm are filled with sap, and in the dry with air. Dry bamboo is therefore largely impregnated with air in a state of capillarity, a condition rendering its expulsion difficult. Drying and seasoning does not cause a collapse or flattening of these pores by shrinkage as is the case to a considerable extent in cereal straws and the smaller annual grasses. In bamboo they retain their shape and size, and therefore their air holding capacity, and no other material in common use carries so large a quantity of imprisoned air. When a mass of bamboo chips is boiled in an open vessel and prevented from floating by being held under the water surface, the expelled air forms a dense dome of froth over the water. Spruce-wood chips similarly dealt with throw up a few air bubbles only. When not

*Pores is here used to denote sap canals or conduits of comparatively large size, visible to the naked eye or with a low power lens. One of them is shown on Plate II, *g*.

prevented from floating, bamboo floats considerably longer than spruce in spite of its greater specific gravity. The greater lightness of spruce permits a much larger proportion of its mass to be buoyed up out of contact with the water, but the whole of the buoyed portion sinks under the surface much sooner than the smaller buoyed portion of the bamboo. The capillary air in the latter resists soakage longer and it cannot wholly sink until this air has been expelled and its place taken by water. In an experiment made with equal quantities of bamboo and spruce chips, thrown into open vessels containing equal quantities of NaOH liquor, and boiled, the spruce took one hour to wholly sink under the liquor, while the bamboo required two and-a-half hours. When forcibly sunk and held under the surface by a perforated plate and then boiled, bamboo continues to throw up air bubbles for two hours. In a closed digester the conditions for getting rid of this air are no better than in an open vessel and chips have been found to still hold air after $2\frac{1}{2}$ hours' digestion. Therefore, in addition to the mass and colloidal resistance common to all materials, we have in bamboo a resisting force peculiar to itself, since complete penetration of the tissues by the chemical solvent cannot take place until the whole of this capillary air has been ejected. Where means are not adopted to force the whole contents of the digester under the liquor,—either by using rotary digesters or screens in stationary ones, the last chips to sink will invariably be found badly digested, not only because they get two hours less treatment than the bulk of the contents, but because they fall into a liquor already weakened by two hours' previous work,—and even when the whole contents are brought under liquor from the start there will be some irregularity in result between the outer and inner tissues of the chip unless liquor of greater strength is used than would be necessary if rapid penetration were secured, so as to ensure it still being of sufficient strength when the interior of the chip is ultimately reached. It seems probable that this capillary air is one of the reasons, if not the chief cause, of irregular digestion hitherto complained of.

6. Spruce is almost equally resistant in all directions to mechanical disintegration, but being a soft wood and of low sp. gr., it has little *mass resistance* to the soakage and penetration of liquor. Bamboo is a hard and heavy material but is strongly resistant to mechanical force in the transverse direction only. To a splitting or crushing force acting longitudinally, it has scarcely any resistance whatever and it is possible by careful dissection to isolate individual filaments or fibre bundles, and to follow them up along the nodes and through the internodes for the

whole length of the culm. It is this facility of separation of its fibrous structure and absence of interlacing with adjoining filaments, together with the large interior surface of the pores exposed to chemical action, (provided the air is expelled), which permits us to remove it from the category of impervious hard woods in which its high sp. gr., and transverse hardness would otherwise place it. It has therefore little *mass resistance* to the action of solvents.

7. The pectous and ligneous constituents of bamboo will be dealt with fully in section B, but their *colloidal resistance* to the penetration of liquor is of a physical nature and finds a place in this section. Pectose is of a gelatinous nature, lignin being more like resin, and, like glue and resin, the first effect of solvent action is, with both, to produce a partially dissolved water-proof colloidal film which protects the tissues it encloses from the further action of the solvent. The influences which overcome this resistance are strong liquors, high temperatures and prolonged duration of digestion, each being, within certain limits, complementary to the others and capable of being substituted for each other. Ligno-celluloses, such as spruce, contain much lignin but no pectose, while pecto-celluloses, such as the smaller fibrous grasses, have a large quantity of pectose and little or no lignin. Bamboo contains both in considerable amount, and its resistance from this cause alone is equal to that of spruce, while its total resistance from mass, colloids and capillary air is greater than spruce.

8. *Nodes* are a prominent feature in all *Gramineæ* but in the annual grasses and cereal straws they are so small and slightly lignified as to give little trouble to the pulp-maker. In bamboo they are large, hard and strongly lignified, and have hitherto been found so difficult to digest that no good results were possible unless they were cut out and rejected. This means not only a considerable loss of raw material but much expenditure on cutting apparatus, the hard siliceous cuticle being very destructive of steel cutting edges. Contrary to what might be expected, the *nodes* are *not* denser than the internodes. On the contrary their sp. gr. is less, so the difficulty found in their digestion is not due to greater density; they contain, however, larger proportions of both pectose and lignin, the treatment of which gives rise to some difficulty. It is not merely the additional quantity of NaOH required to resolve them, since digestions with NaOH in large excess of the amount required fail to give good results, but the greater and more persistent colloidal resistance exercised by the larger and thicker masses of pectous and ligneous

matter in which the cellulose is buried has to be overcome. The average proportion of nodes to the whole culm is shown in the following table :—

TABLE I.

Percentage proportion, by weight, of nodes to whole culm in dry seasoned bamboo.

	Per cent.
C. pergracile	6
Melocanna bambusoides	7
B. Tulda	8½
B. polymorpha	9
B. arundinacea	15

9. A bamboo *culm* is light and buoyant solely because it is hollow. Its component wood is as heavy as many of the hard woods. Coniferous wood on the other hand is extremely light, on the average less than half the weight of bamboo. Judged solely by this standard it would appear to be an impossible material for our purpose, but it is saved from rejection on this score by the features mentioned in paragraph 6. The following table gives the sp. gr. of the five species we are dealing with, together with one other (*B. Balcooa*), introduced in order to show how heavy a bamboo may be. For comparison, the sp. gr. of several woods in common use for pulp making are also given.

Specific gravity.

TABLE II.

Specific gravity of two years old seasoned bamboo.

		Internodes.	Nodes.	Internodes crushed.
Melocanna bambusoides		·8410	·8091	
B. arundinacea		·8704	·8351	
B. Tulda		·9056	·7682	
B. polymorpha		·9555	·9170	1·0100
C. pergracile		·9555	·9068	·9891
B. Balcooa		1·0090	·9876	
White pine	·3485			
Spruce	·4087			
Fir	·3545			

It will be noted that *B. Balcooa* is actually heavier than water and therefore ranks in weight with some of our heaviest hard woods. The nodes are in all cases lighter than the internodes.

Moisture.

10. Air-dry bamboo differs considerably from other materials in its capacity for holding and retaining hygroscopic moisture. This is due to the large interior surface which the pores expose to the effect of changes in the humidity of the atmosphere-changes which, in a climate like that of India, with its distinct wet and dry seasons, are naturally greater than in temperate latitudes where the hygrometric state of the air is more constant throughout the year. I have tested samples after a prolonged period of dry weather to contain 4·75 per cent. of moisture only. The same sample, kept until the monsoon season was well advanced, carried 12 per cent. and I have found as much as 15 per cent. in exceptional cases without it being noticeably damp either in appearance or to the touch. It is also quickly sensitive to merely temporary and slight changes in atmospheric conditions ; thus, the sample mentioned above as having 4·75 per cent. of moisture after a lengthy period of dry weather, contained 9 per cent. a few days later, one day of showery weather having intervened. It is therefore highly necessary, when making tests of yield, to ascertain the moisture and either deal with the results on an absolutely dry basis or on a recognised standard of normal air-dryness, otherwise contradictory results from this cause alone may easily ensue. Such a precaution is always taken in laboratory work but is sometimes overlooked in factory tests, and it is quite possible some of the variations reported may be, in part, due to such neglect. A 10 per cent. variation in the moisture contents of the raw material may easily be responsible for 4 to 5 per cent. difference in the reported pulp yield. The English normal air dry standard of 90 per cent. dry substance and 10 per cent. of moisture appears to be a fair mean throughout the year and I have therefore adopted it for both raw material and product.

Mechanical treatment.

11. In their treatment of bamboo, it has been natural for experimentalists to rely largely upon their experience with coniferous wood to which it has many points of resemblance in appearance, structure and chemical constitution. Its preliminary preparation for digestion has therefore consisted of cutting out and rejecting the nodes, which have been found intractable at the pressures hitherto available, and reducing the internodal portions to chips. But there does not appear to have been sufficient attention given to those features in which it is markedly dissimilar to wood. In chemical constitution it presents no difficulty. As with all chemical reactions, if the requisite quantity of reagent is present under suitable conditions, it is bound to do its work, *provided it can get at it.* But in its combined mass, colloidal and capillary air resistance to the penetration of solvents,

bamboo presents difficulties of treatment as to its internodal portions greater than those of wood, and so much greater in the case of the nodes, that no serious attempt has been made to deal with them. In short, the special difficulties met with in bamboo are physical and not chemical and must be, and can be, dealt with by physical and mechanical means. If bamboo is *crushed* instead of chipped, its special difficulties disappear, not only with internodes but also in the case of nodes. The crushing requires to be very thoroughly done, my best results having been obtained at the Allahabad Exhibition (in December 1910), by passing the culms split in half (*i.e.*, split once longitudinally), through the heavy cane crushing rollers of a modern sugar plant. With small thin walled bamboo, splitting is not necessary. This treatment results in the production of loose masses of finely divided fibrous bundles somewhat like hanks of coarse tow. The crushing fracture runs along the capillary tubes splitting them open, expelling the air and exposing their inner surfaces to immediate attack by the chemical solvents. The nodes almost disappear, it being difficult to tell what portion of the fibrous mass was node and what internode. The air resistance is totally destroyed thus saving the time occupied by its expulsion in the digestion of chips, and reference to Table II will show that its expulsion is so complete that the sp. gr. is actually slightly raised. When thrown into water, crushed bamboo of the heavier species sinks at once, while the lightest float for ten minutes only ; thus we get rid of the floatation trouble with its resultant irregularity of digestion referred to in paragraph 5. The colloidal resistance also largely disappears. This will be understood by the somewhat rough analogy of the behaviour of resin in the process of making resin soap. If a *lump* of resin is thrown into a boiling solution of NaOH, there immediately forms on it a thin colloidal film of partially dissolved resin which exercises a water-proofing protective effect on the interior of the lump and considerably delays its saponification. But if the resin is first crushed to powder and added in that condition slowly to the boiling liquor and prevented by stirring from again cohering into a mass, complete and rapid saponification results, the immensely greater surface area, provided by the small particles to the action of the liquor, preventing the establishment of colloidal protection. Similarly in crushed as compared with chipped bamboo, the much larger surface area presented, and the reduction of pectous films and ligneous masses from thick to thin and large to small, very considerably reduces the colloidal resistance. By crushing, the node difficulty is entirely removed and the bamboo can be dealt with as a whole, the nodes being reduced to a physical and mechanical condition indistinguish-

able from that of the internodes. With their colloidal and air resistance thus destroyed, their additional pectous and ligneous contents sink into insignificance (in relation to the whole mass). Thus, in *B. polymorpha* the total of these constituents in the internodes is 36·08 per cent. In the nodes it amounts to 44·32 per cent., but in the whole mixed mass it is only 36·82 per cent. Crushing therefore entirely eliminates the two difficulties peculiar to bamboo, *viz.*, its capillary air and the obstinacy to reduction of its nodes, and also very largely reduces its colloidal resistance. In regard to the difficulties which remain, it may be said to remove the material from the category of the woods into that of the straws to which it has now a much closer resemblance, and in fact, from now onwards, the analogy of, and the experience derived from the treatment of straw, will be much more useful to us than those of wood.

Bulk and volume.

12. The only drawback to crushing is the increase in the bulk of the mass which it entails. The effect is to reduce the output from the digesters by reason of their not being able to contain so much dead weight of raw material. This is compensated for to some extent by a saving in time and chemicals, as crushed material digests in three-fourths of the time required by chips and in a weaker liquor. What remains in the way of objection is much more than counterbalanced by the simpler and easier digestion conditions which it permits, in the economy of being able to utilise the nodes, and in the freedom of the resultant pulp from imperfectly digested matter. A ton of bamboo chips occupies 90 cubic feet of space and requires 336 gallons of liquor to cover it after it has ceased to float, which is in the proportion of $1\frac{1}{2}$ to 1, or 1,500 cc. to 1,000 grms. When crushed, although the sp. gr. of the individual particles is greater, yet the bulk of the whole mass is increased to just about double by reason of the greater number and total aggregate of the spaces or voids between them, even when tamped down. A ton then occupies about 180 cubic feet and requires 672 gallons to cover it. With the percentages of soda required this means a comparatively weak liquor of 12° or 13° Tw. The danger of the destruction of fibre by strong liquors is therefore to a large degree avoided. The advantages which crushing gives over chipping may be summarised as follows :—

(*a*) It economises the nodes and saves the cost of cutting them out.
(*b*) It saves 2 hours in the period of digestion.
(*c*) It permits a weaker liquor to be used, thus reducing the danger of fibre loss by hydrolysis.
(*d*) It gives a more evenly digested product.

SECTION B.

Analytical.

Scheme of analysis.

13. The scheme of analysis affording the most useful information to the pulp-maker is one based on the varying solubilities of the component, or groups of component, substances composing the raw material. The behaviour of the fibre under nitration or mercerisation while important to the textile manufacturer, is of little interest in the case of paper fibre and is therefore omitted here. The important thing is to arrive at the amounts of substances present that exercise variable effects upon the reagents employed in the digestive process.

The scheme adopted is as follows :—

(*a*) *Water Extract.*—Matter soluble in water at 100°. In bamboo, chiefly starch and its secondary or transformation products with a small amount of soluble salts.—No tannin present, may be separated into starch secondary products which are soluble in cold water, and starch as such, which is only soluble in boiling water or in cold weak (0·6 per cent.) NaOH.

(*b*) *Fat and wax.*—Soluble in hot mixture of ether and alcohol. Exists principally in the cuticle. No resin present. Small in quantity and of little importance, and will usually be convenient to consider in conjunction with the next group as it is also soluble in 1 per cent. NaOH.

(*c*) *Pectose.*—Pectous matter, soluble in 1 per cent. NaOH at 100°.

(*d*) *Lignin.*—Ligneous matter which together with cellulose forms the true wood substance. Separated by the *Sodium hydroxide-chlorine-Sodium Sulphite* method of Cross and Bevan. Soluble also in strong NaOH at temperatures above 130° but with hydrolysis and loss of fibre.

(*e*) *Cellulose.*—The insoluble residue from (*d*).

(*f*) *Total ash.*—Mineral matter, chiefly silica with varying amounts of soluble earth salts. *Not included* in the percentage proportions because each of the separations (*a*), (*c*), (*d*) and (*e*) carries out with it its own complement of silica or salts, or both. To include it would therefore have the effect of reckoning it twice.

There remains *hygroscopic moisture* or water of condition. As this is variable in amount and not in chemical union with the material it need not be quoted nor included in the percentage

determinations, which are all made on the *absolutely dry substance.* To avoid the error which is possible owing to changes in the constitution of the material caused by repeated drying of the same sample, separate portions of it are used, *viz.*, one each for (*a*), (*b*) and (*c*) and one for (*d*) and (*e*).

14. As crushing settles the node difficulty we have now to deal with the analysis of the bamboo as a whole. The proportional weight of nodes to the whole is first ascertained and the analysis samples made up of internode and nodal portions in accordance therewith, the internodes being reduced to fine shavings and the nodes to coarse filings. To give an idea of the extent to which the admission of the nodes affects the average composition of the whole, the following results on a few typical samples are given :—

TABLE III.

Analyses of internodes and nodes in seasoned bamboo.

	Per cent. of whole.	Water extract.	Fat and wax.	Pectose.	Lignin.	Cellulose.	Ash.
		100					
B. polymorpha, Internodes . .	91	8·70	1·04	19·15	15·29	55·82	3·87
„ nodes . . .	9	9·83	1·40	25·04	17·60	46·13	4·50
Average of the whole . . .	..	8·80	1·07	19·68	15·50	54·95	3·92
C. pergracile, Internodes. . .	94	7·96	·90	22·14	15·10	53·90	2·50
„ nodes . . .	6	9·07	1·24	26·27	16·72	46·70	4·20
Average of the whole . . .	..	8·03	·92	22·39	15·20	53·46	2·60

The chief differences are that the nodes show a considerably larger amount of pectose, with a smaller increase in lignin, sufficient together to account for their greater consumption of NaOH when digested by themselves, and for their obstinate resistance to penetration. When crushed and mixed with the internodes, the resistance disappears, and the total non-cellulose so slightly raised that its effect on NaOH consumption is negligible.

Starch.

15. Before proceeding to deal with the analysis of normal seasoned bamboo, one disturbing feature peculiar to it must be disposed of. In the annual reproduction of new culms, bamboo is unique, in as much that the whole of these reach their

full height and girth within a period of from two to four months. This enormous and rapid effort may result in growth equalling, in actual dry weight, one-fifth of that of the whole clump, and the normal activity of its root and leaf systems would be wholly inadequate to support this growth were these not aided by its power of storing up large reserves of plant food in anticipation, chiefly in its roots but also to a very considerable extent in its culms. From these reserves the young shoots draw the major portion of the material required for building up of their tissues. These reserves consist of starch in its solid and granular form. During the process of its transformation into woody tissue it breaks down, or metamorphoses, into several groups of secondary products (of which dextrose is a type), all of which are soluble in cold water and therefore capable of being readily assimilated by the plant. Both as starch and as secondary starchy matter, it at all times and seasons forms a considerable constituent of bamboo and one not met with to any appreciable amount in other raw materials. But its special interest to us at the present stage of these proceedings is its liability to large variation at different seasons of the year. As the young culms make their appearance at about three to five weeks after the commencement of the south-west monsoon, we find the largest reserve stores existing then and find abundant proof that the first few weeks of the monsoon season, as also of the period of showery weather preceding it, are utilised to collect them ; and we also find, as we should expect, that they are at their lowest at six to eight weeks after the monsoon has ceased and when the young stems are fully grown. But should a period of forcing, *i.e.*, showery weather, intervene during seasons which are usually dry, or if the district is visited by the short north-east monsoon, the habit of the plant asserts itself and storage takes place, resulting in the upsetting of the normal relative percentage of its constituents. I have found, for instance, in a bamboo cut during the height of the dry season a total water extract of 9 per cent. on the dry substance. A period of unusual and unseasonable showery weather, lasting for three weeks, then intervened. A culm cut from the same clump then yielded 23 per cent. with, of course, a relative reduction of the cellulose which was only 37 per cent. But it is important to note that this same culm, preserved in a dry atmosphere for five weeks yielded then only 15 per cent. of water extract, which three months later had fallen to 11 per cent. with corresponding rises in the relative percentage of cellulose. This can only mean that the starch is, in its secondary forms, capable of being oxidised by air and dispersed in the atmosphere, and that such oxidation is an integral part of the process of seasoning, and

it forces us to the conclusion that the maximum yield of cellulose can only be obtained from bamboo which is not merely dry but is also *seasoned.* Such seasoning is well understood by the native of this country who, being desirous of increasing the durability of his building bamboos, hastens the process by immersing them, immediately after being cut, in running streams or tidal creeks for several weeks. He thus washes out the soluble starch products and increases the durability by abstracting the matter upon which fungoid and insect enemies feed. His explanation is that he drowns the insects and their larvæ which are already there, but the green growing bamboo is remarkably free from these. We have here another possible cause for irregular yields, and, to avoid it, it will be necessary to cut the bamboo at the season when its starch contents are at their lowest and to allow a period of seasoning to elapse before using. In ordinary circumstances this will be the case without special precautions being taken, as it will generally be cut after the close of the monsoon and several months of good seasoning weather will intervene before it reaches the mills. But it should not be cut too soon after the monsoon or before the young culms have attained their full growth, and in districts where the north-east monsoon prevails it will probably be found advisable to defer cutting until several weeks after it has ceased. Cut at the proper time and with a sufficient period of seasoning, the water extract is reduced to a fairly stable average of from 10 to 13 per cent. in one year old and 7 to 10 per cent. in older culms.

16. The matter of the young growing culms may here be disposed of. The experiments of the late Thos. Routledge, about 35 years ago, were made with these. The experience now available of the treatment of lignified materials was not then at his disposal. He had therefore, perforce, to use methods and plant suitable only for pecto-celluloses, and therefore turned naturally to bamboo in its immature and unlignified state. But the young shoots are, at this stage, protected by hard, closely clinging hairy siliceous sheaths springing from each node and enveloping the whole internode. He succeeded in proving the usefulness of the body of the culm, but the sheaths proved an insuperable difficulty. They could not be detached except by slow and expensive hand labour and, if left on, they were quite incapable of reduction. They are so still, notwithstanding improved methods of treatment. With the sprouting of branches as the culm approaches maturity (their purpose being by then accomplished), they split away from the stem, wither and fall off. As the mature culm can now be dealt with, it is not necessary to interfere with the growing stem, and, indeed, to do so would be the most effective means of in-

juring and possibly destroying the capacity of the plant for rapid and regular natural reproduction which is one of its chief recommendations for our purpose. As a matter of interest and information and to illustrate the changes which occur with maturity, an analysis of it is given when three parts grown, at which age the branches begin to sprout and lignification begins. At the half-grown stage there is no lignin. I also include, for comparative purposes, analyses of a typical pecto-cellulose (Bhabur grass), a cereal straw, and a ligno-cellulose (Spruce wood).

17. In the selection of samples for analysis it has not been possible to obtain accurate evidence of age in all cases. The Forest Economist has pointed out that except in the case of the one year old culms, age must be a matter of considerable uncertainty. In the following table, specification as to age may be accepted as correct in the case of one year old and as *probably* correct in the case of two years old bamboos. These latter may be older but not younger. No. 6 is certainly more than two years, but may be three, four or older.

TABLE IV.

Analyses of absolutely dry seasoned bamboo on samples representing whole culm.

No.	——	Water extract.	Fat and wax.	Pectose.	Lignin.	Cellulose.	Ash.
		100					
1	Young culm, ¾ grown	13·10(*a*)	·75	24·48	5·62	56·05	2·61
2	*B. Tulda*, 1 year .	11·40	·90	22·09	13·33	52·28	2·72
3	Ditto 2 years .	7·86	1·01	24·33	13·80	53·00	2·56
4	*B. polymorpha*, 1 year	11·60	1·07	17·95	15·66	53·72	4·73
5	*B. polymorpha*, 2 years	8·95	1·05	19·55	15·74	54·71	3·97
6	Ditto 3 years or more.	6·90	·95	21·57	15·96	54·62	2·18
7	*B. arundinacea*, 1 year.	12·42	1·15	21·95	15·46	49·02	2·56
8	*B. arundinacea*, 2 years.	8·48	1·17	24·39	15·64	50·32	1·60
9	*C. pergracile*, 1 year	11·57	1·04	20·74	14·96	51·69	3·37
10	Ditto 2 years .	7·96	·92	23·09	15·30	52·73	2·57
11	*Melocanna b.*, 1 year	15·66	1·77	10·54	21·43	50·60	3·05

(*a*) No solid starch.

TABLE IV—*contd.*

Analyses of absolutely dry seasoned bamboo on samples representing whole culm—contd.

No.	—	Water extract.	Fat and wax.	Pec tose	Lignin.	Cellu-lose.	Ash.
12	*Melocanna b.*, 2 years	13·57	1·70	12·77	21·73	51·23	2·25
13	Bhabur grass, cut before flowering.	9·08(*a*)	2·64	35·57	3·40	49·31	6·20
14	Wheat straw, after ripening.	7·79(*b*)	1·24	29·06	10·23	51·68	2·70
15	Spruce wood . .	6·73(*c*)	3·02(*d*)	0·00	35·76	54·49	0·05

(*a*) Colouring matter, soluble salts and trace of starch.
(*b*) Colouring matter, soluble salts and no starch.
(*c*) Gum and mucilage, no starch.
(*d*) Resin, no fat or wax.

18. A study of the above table shows that lignification is practically complete at the age of one year, little change occurring afterwards either in this or the cellulose percentage. The chief alteration effected by age is the reduction of the water solubles and the increase in pectous matter. The former is a result of the diminished sap activity as is also the smaller amount of ash :—the silica remains about the same but the soluble salts decrease. The increase in pectous matter appears to be the only cause of the greater difficulty of digestion of older culms hitherto experienced, and, as in no case is the additional quantity more than will account for an extra 1 per cent. of soda, this greater difficulty can only be due to the additional colloidal protection and cementation of the whole mass thus given. Since crushing destroys this, there would appear now to be no sufficient reason why culms of all ages of the same species should not be mixed and digested together. Neither is there any reason apparent to prevent the mixing of *B. polymorpha* and *C. pergracile.* These grow together and it may therefore be convenient in factory practice to deal with them mixed and as a whole. With none of the other species is the question of mixture likely to occur as they each are dominant in their own districts. In degree of lignification, bamboo comes between the pecto-celluloses, such as Bhabur and Esparto grasses, and the ligno-celluloses, and may be described as a pecto-ligno-cellulose. *Melocanna bambusoides* exhibits such marked differences from the other four species

that it stands in a class by itself. It has a greater starch storage power than any of them, has considerably less pectose and considerably more lignin.

19. In its starch contents, bamboo differs entirely from any of the other materials in common use. As has already been remarked, seasoning reduces this considerably, but in thoroughly seasoned culms of all ages the average water solubles will still be about 9 to 10 per cent. except with *Melocanna* which will show 2 or 3 per cent. more. The proportion of solid to secondary starch products will vary according to whether the plant is storing or using plant food, but usually it will be cut at a season when the latter process is in progress. A detailed analysis of one cut at this period, which showed 13·57 per cent. of water solubles, gave the following figures :—

	Per cent.
Starch, solid	2·70
Starch in secondary forms	8·33
Colouring matter and soluble salts	2·54
	13·57

It might be assumed that as the whole of this is soluble in water, the soda contents of the digestion liquor are unaffected by it. This, however, is not the case. In strong solutions, not under 4 per cent. of NaOH, it does neutralise a considerable amount, and, further, in doing so it combines to form an insoluble dark brown precipitate with the secondary products, (the combination with solid starch giving no ppt. or colour reaction), *which the pulp filters out and which is unbleachable* and seriously affects the final bleaching process with B. P. The amount of NaOH which it abstracts from the liquor I have found to be equal on the average to 1 per cent. on the raw material for each 4·5 per cent. of water solubles shown in analysis. Therefore, in the digestion of material containing 9 per cent. of water extract and requiring 18 per cent. of NaOH to effect complete digestion, 2 per cent. is used up by the starchy matter, and in the subsequent treatment with B. P., from 6 to 8 per cent. more B. P. will be required to bleach up to standard white than would be necessary if the starch was not there. Since the whole is soluble in hot water, obviously the right course is to make a preliminary boiling in water the first step in digestion. After thus exhausting the water solubles, the ordinary digestion can then proceed with a smaller quantity of NaOH. The large and variable content of starch is one of the important features indicating the necessity of considering bamboo as

a material requiring methods of treatment suitable to its peculiarities and one to which our experience of other cellulose producers has but limited application, and is one of the chief causes of the high and variable bleach cost figures which have been reported.

20. The *pectose* is readily soluble in boiling NaOH solutions, but gelatinises at the higher temperatures employed in digestion and is, therefore, liable to become mechanically bound to the cellulose and difficult to wash out in the case of material treated in chip form. When this occurs the difficulty of the subsequent bleaching is considerably increased. The smaller the particle the less will this mechanical binding occur in the interior,—hence the advantage of crushed material is very marked upon this point. With *pectose, fat and wax* may conveniently be grouped as the latter is insignificant in amount and is soluble under similar conditions. Together they neutralise or abstract from the digestion liquor ·32 per cent. of NaOH on the raw material for each 1 per cent. found on analysis.

21. Unlike pectose, *lignin* is not soluble in weak solutions nor at temperatures below 130°, and with strong solutions and high temperatures the danger of serious hydrolysis and destruction of fibre comes into play. The weaker the solution and the lower the temperature, the higher the cellulose yield, but the minimum limit with both is the point at which lignin is no longer soluble. Its resolution is essentially a process of saponification and it must be borne in mind that it has to be transformed into a soap which remains soluble *in the cold*, otherwise precipitation on the pulp would occur during the subsequent washing. Crushed material, by its large bulk, entails the use of a large volume of comparatively weak liquor, and this, to a considerable extent, eliminates the hydrolysing tendency of strong liquor. In general, the digestion liquor will not exceed 12° Tw. In liquors of this strength, the lowest temperature at which the permanently soluble saponification of the lignin can be effected is 150° and the consumption of NaOH is equal to ·66 per cent. on the raw material for each 1 per cent. found on analysis. The duration of digestion required is 3 hours. The experiments to arrive at these results were carried out on material scraped to extremely fine and thin shavings in order to reduce penetration resistance to a minimum and from which water solubles, fat and wax, and pectose were previously extracted, and they give us the absolutely irreducible minima of conditions necessary for digestion under nearly perfect resistance conditions, *viz.*, a temperature of 150° for three hours using liquor of 12° Tw. The problem of how far it is necessary to raise these conditions in order to overcome

the greater difficulties presented by crushed material as compared with scraped, under the limitations of 'overhead' digestion which compels us to deal with pectose and lignin together, will be dealt with in Section C.

22. As a result of analysis and the resolution experiments arising from it, we are now in a position to form an approximate estimate of the quantity of NaOH necessary to effect the separation of cellulose from non-cellulose. It must be understood that we are here dealing with complete but *bare* digestion only, and do not take into account any large excess of NaOH which it may be considered advisable to use in order to obtain a bleaching effect for the purpose of assisting the subsequent bleaching process. But since all chemical reactions require a small excess of the reagent in order to ensure complete combination, I include in the last column of the following table ·5 per cent. for this purpose. This is the minimum amount I have found to be necessary. Digestions showing ·5 per cent. of free NaOH after the operation is complete will usually be found satisfactory. We may estimate on the analyses of 2-year old culms which will represent very nearly an average of the whole crop, any slight favourable differences in one year old being balanced by corresponding unfavourable ones in the culms more than two years old.

TABLE V.

Approximate amount of NaOH required to effect the resolution of fat and wax, pectose and lignin (starch being previously extracted).

	Per cent. of pectose, fat and wax at ·32 NaOH for each 1 per cent.	Per cent. of lignin at ·66 NaOH for each 1 per cent.	Per cent. of NaOH on dry bamboo.	Per cent. of NaOH on N.A.D. bamboo + ·5 excess.
B. Tulda	25·34—8·11	13·80— 9·11	17·22	16·00
B. arundinacea . . .	25·56—8·18	15·64—10·32	18·50	17·15
B. polymorpha . . .	20·60—6·59	15·74—10·39	16·98	15·79
C. pergracile . . .	24·01—7·68	15·30—10·10	17·78	16·51
Melocanna b. . . .	14·47—4·63	21·73—14·34	18·97	17·58

So far as analysis can teach us, the figures given in the last column represent the irreducible minima with which bare but complete resolution can be accomplished under nearly perfect conditions of resistance. Anything in excess of these amounts which may be found necessary will be due to conditions of material, or digestion, other than the non-cellulose contents of the material.

SECTION C.

Digestions.

23. The methods of digestion applicable in factory practice for the isolation of cellulose by bringing into solution the other constituents of the material are three in number and are known as the Sulphite, the Soda and the Sulphate processes. The liquor employed in the first of these carries in solution bi-sulphite of lime,—or when dolomite limestone is used, a mixture of the bi-sulphites of lime and magnesia,—and free sulphur dioxide gas. The soda process depends on the saponifying effect of sodium hydroxide (caustic soda). An important feature of this process is the recovery of the reagent from the spent liquors, by evaporation and calcination, in the form of carbonate of soda. This is regenerated to caustic soda by boiling with quicklime and re-used. It is thus possible to recover 80 to 90 per cent. of the whole. The loss is made up with fresh carbonate added during the causticising process. The sulphate method is a modification of this; the loss on recovery being made up with sulphate of soda which is changed during calcination to sodium sulphide, and the ultimate liquor contains as its active ingredients, caustic soda ($NaOH$) and sodium sulphide (Na_2S).

Sulphite digestions.

24. The advantages possessed by the sulphite process over the soda are, (*a*) that when conditions exist favourable to the manufacture of the liquor it is less costly, (*b*) it exercises a less destructive effect on the fibre, so its yield of cellulose is slightly higher, and (*c*) it does not, like soda, degrade the solubles of the material to a brown colour which stain the pulp. The latter is therefore of a fairly good yellowish white colour in the unbleached state and can be used for many purposes (such as the cheaper grades of newspaper), without further bleaching. But this advantage is largely lost where

better grades are concerned which entail bleaching to a white shade, for it is frequently the case that the brown soda or sulphate pulp is more easily bleachable than the pale yellow sulphite. This is especially the case with sulphite pulps made from resinous and dark coloured woods, hence it is chiefly confined to the treatment of Spruce which has little resin and possesses a good natural colour. When colour difficulties are present, it is not suitable unless a market exists for the pulp in its yellow unbleached condition. But bamboo pulp is so emphatically suitable for better uses that it would be misplacing it entirely to devote it to purposes for which an unbleached yellow cellulose is good enough, and the cost of bleaching bamboo sulphite pulp is so much greater than for bamboo soda or sulphate pulps that any economy of sulphite over soda liquor is lost.

25. There is also the question of its suitability to tropical conditions to be considered. Sulphur dioxide is a volatile gas and its successful absorption in water, or lime-water, is adversely affected by temperature, either of water or atmosphere, higher than those normal to northern latitudes. Even in Europe and North America much difficulty is experienced during abnormal heat waves, and I am unable to see how this process could be successful where such high temperatures are normal during the greater part of the year, unless by the adoption of refrigeration, the cost of which would destroy any advantage of economy the process possesses.

26. Notwithstanding the foregoing considerations it seemed desirable not to overlook any special virtues it might possess for the treatment of bamboo. It was accordingly given a fair trial. As the liquor is corrosive of iron or copper the digestions were conducted in gas-tight earthenware jars fitted inside the digesters. It was found that bamboo is very sensitive to charring in liquors of a greater density than 7° Tw. or at temperatures above 150°, or in liquor containing an insufficient proportion of free sulphur dioxide ; but in a comparatively weak liquor of the following composition it digested perfectly in ten hours, of which 4 were occupied in slowly raising the temperature to 145°, it being then maintained at that point for a further six hours :—

	Per cent.	
Total SO_2	3·60	Density 5° Tw.
Combined SO_2	1·46	
Free SO_2	2·14	
Combined lime	1·28	

The resultant pulp amounted to 49 per cent. on the original weight and was of a yellow straw colour. Bleaching reduced it to 46·3 per cent. and it required 40 per cent. B. P. (on weight of unbleached pulp) to bring it up to standard white. This was the best of several experiments and no variation in liquor contents, time or temperature produced any better results. Such a bleaching cost is not economically permissible and it seems clear that the sulphite process, even if workable in the tropics, has no advantages for the production of bamboo pulp.

Soda process.

27. The conclusions arrived at in the Sections A and B considerably clear the way for both soda and sulphate treatment. We know that for digestion of material which has had its mass, air and colloidal resistance nearly entirely destroyed (*i.e.*, in fine shavings), and from which the starch contents have been extracted, a temperature of 150° is essential for at least three hours, with consumption of NaOH as per Table V : that these conditions are necessitated by the chemical composition of the bamboo and that anything required in excess of them will be due to the resistance still remaining in the crushed material. The extent to which such excess is permissible is governed chiefly by conditions of yield of cellulose and its capacity for bleaching. As a general rule, the more severe the digestion conditions, the lower the yield but the higher the bleaching economy, and to gain the latter it may pay to sacrifice the former to some extent. The problem therefore is, to arrive at those conditions which most economically balance the two.

28. The cellulose shown by analysis exists in two forms :— the α-and β-cellulose (of Messrs. Cross and Bevan). α-cellulose is that which is strongly resistant to alkaline solutions of any strength and temperature; β-cellulose is a less resistant form which may be seriously attacked under drastic digestion conditions. Treatment designed to destroy the whole of the latter will usually result in yields of about 35 per cent. It therefore seems probable that β-cellulose represents about one-third of the whole, and its conservation, so far as is consistent with obtaining a good bleaching pulp, has an important bearing upon the economic result. The influences affecting its destruction are strong liquors, high temperature and prolonged duration of digestion. The first is settled for us by the chemical requirements of the case and the large volume required to cover crushed material, so that as a rule the liquors will not exceed 12° Tw. At this strength its destructive effect is not serious except at very high temperatures. Saving of time, also, is a most important factor in the economic

conditions governing modern factory practice. The fixed charges incurred by a factory for interest and depreciation of plant, salaries, wages, etc., bear so high a proportion to the total cost of pulp per ton, that the amount of output becomes of supreme importance. The greater the production, the less the ton cost for these items, and it may easily be of so much importance that it may pay to sacrifice chemicals, or even yield, in order to save time and thus increase the output. To take a concrete case :—it is conceivable that a yield of 40 per cent. obtained at a cost of 20 per cent. of NaOH in 6 hours may pay better than one of 44 per cent. obtained by the use of 18 per cent. in 12 hours. Our best guide on this point is modern factory practice which declares that 8 hours is the outside limit which can be allowed for digestion inclusive of the time required for filling and discharging the digester, which means 6½ or 7 hours' actual digestion, and the further that this can be reduced, without unduly raising the chemical consumption or reducing the yield, the better. Temperature therefore is the only factor permitting of any considerable degree of latitude. Our present problem therefore is, to take a specimen case :—what amount of NaOH, temperature and time are necessary to secure complete but bare digestion (we are still at this stage leaving out of account the bleaching effect of an excess of NaOH) of crushed *B. polymorpha*, the minima being 15·79 per cent. NaOH, 150° of temperature, and 3 hours, the maximum time permissible being 6½ hours.

29. It is not necessary to detail the long series of experiments which were required to settle the above query, but it may be said that there was, with liquors not exceeding 12° Tw., incomplete digestion in 6½ hours at 153° but satisfactory digestion at 162°. The destruction of fibre up to that limit scarcely concerns us as the necessity for complete digestion is paramount. Between 162° and 170° the additional loss was small and might be considered compensated for by a saving of one hour and a slight improvement in colour. At 177° the loss was serious, and at 183° extravagant. It was, however, found that the advantages of high temperature in more rapidly overcoming penetration resistance and improving colour could be obtained, without incurring the penalty of loss of fibre, by conducting digestion at 177° for not more than 1 hour and then reducing to 162° for the remainder of the time. This resulted in the saving of 1½ hours, digestions thus managed being as good in 5 hours as others conducted at a uniform temperature of 162° for 6½ hours. It is reasonable to assume that the penetration of the tissues takes time and that fibre destruction is not likely to take place until the pectous and ligneous matter is at least thoroughly softened, and it would seem that this part of the process

occupies at least one hour at 177°. A similar system of managing temperatures is in use in the manufacture of soda and sulphate wood pulps. The final conclusions drawn from this series of experiments are as under :—

TABLE VI.

To resolve the non-cellulose constituents of crushed and starch-free bamboo requires treatment as follows.

—	NaOH.		INITIAL.			SUBSEQUENT.			Unbleached yield.	B. P.		Bleached yield.	Unit cost.
	Per cent.	Tw.	Temp.	Press.	Hrs.	Temp.	Press.	Hrs.		(a) Per cent.	(b) Per cent.		
B. Tulda . .	16	9¾	170	100	1	162	80	4	48·7	32	15·6	43·5	7·12
B. arundinacea .	17½	10½	177	120	1	162	80	4	46·5	37	16·2	42·0	7·91
B. polymorpha .	16	9¾	177	120	1	162	80	4	50·0	36	18·0	44·5	7·41
C. pergracile .	16½	10	177	120	1	162	80	4	48·7	35	17·0	43·5	7·45
Melocanna b. .	18	10¾	177	120	2	162	80	4	47	42	19·7	42·5	8·33

(*a*) Per cent. on unbleached pulp.
(*b*) Per cent. on raw material.

The quantities of NaOH used are in fair agreement with the estimated requirements given in Table V. In no case do they exceed the latter by more than ·5 per cent. which may be regarded as the additional margin of safety to be provided against the slight variations in quality, composition and condition of raw material when dealt with in large quantities. *B. Tulda* being slightly less lignified than the others required a lower initial temperature. *Melocanna* being more lignified required an extra hour at the higher temperature. The unbleached yield is, relatively to the bleached, too high, indicating that the former includes some precipitation of colouring matter which might profitably be removed by a larger excess of NaOH, with a subsequent reduction of B. P. The column " Unit cost " is explained in the following paragraph.

Soda bleaching.

30. During the resolution and saponification of the non-cellulose matter by NaOH, coloured compounds, or groups of compounds, are formed which degrade the colour of the pulp to brown, but a large excess of the reagent has the effect of either reducing some, or all, of these to a lighter shade of colour, or of holding

them more completely and permanently in solution so that they can be more thoroughly washed out of the pulp. The colour of the unbleached product can thus be considerably improved and the subsequent consumption of B. P. reduced. But NaOH in excess of that required for the resolution of the non-cellulose has, at the temperatures employed, a seriously destructive effect on the fibre, so its use for this purpose is limited by the extent to which it is profitable to sacrifice yield in order to gain colour. It becomes a matter of balancing the costs of raw material, NaOH and B. P. against the ultimate yield of bleached pulp. To a factory in India these may be taken, for our present purpose, to be Rs. 15, Rs. 75 (with aid of recovery plant) and Rs. 125 per ton respectively. Slight differences in fuel cost for the variations in temperature and time employed may be neglected as too small to appreciably affect the nett results. If these items be reduced to units and divided by the bleached yield, we obtain a series of unit cost figures giving us a relative and comparative view of the economic results. Taking bamboo (B) as 1, NaOH (n) will be 5 and B. P. (b) 8·33, final bleached yield being represented as (y).

$$\therefore \quad \frac{(B \times 1)+(n \times 5)+(b \times 8{\cdot}33)}{y} \quad \text{Unit cost.}$$

The following gives the average results of experiments made to determine how far excess NaOH may be profitably employed to reduce colour ; time and temperature being in each case 177° for 1 hour and 162° for 4 hours :—

No. I. 16 per cent. NaOH, unbleached yield 49 per cent., required 36 per cent. B. P. (17·6 on raw material), bleached yield 43·2.

No. II. 18 per cent. NaOH, unbleached yield 47 per cent., required 29 per cent. B. P. (13·6 on raw material), bleached yield 43·0.

No. III. 20 per cent. NaOH, unbleached yield 44 per cent., required 23 per cent. B. P. (10·1 on raw material), bleached yield 41·5.

No. IV. 22 per cent. NaOH, unbleached yield 41 per cent., required 20 per cent. B. P. (8·2 on raw material), bleached yield 39·0.

Unit cost being :—

$$\text{No. I.} \quad \frac{(100 \times 1)+(16 \times 5)+(17{\cdot}6 \times 8{\cdot}33)}{43{\cdot}2} = 7{\cdot}56$$

$$\text{No. II.} \quad \frac{(100 \times 1)+(18 \times 5)+(13{\cdot}6 \times 8{\cdot}33)}{43} = 7{\cdot}05$$

$$\text{No. III.} \quad \frac{(100 \times 1)+(20 \times 5)+(10{\cdot}1 \times 8{\cdot}63)}{41{\cdot}5} = 6{\cdot}84$$

$$\text{No. IV.} \quad \frac{(100 \times 1)+(22 \times 5)+(8{\cdot}2 \times 8{\cdot}33)}{39} = 7{\cdot}14$$

The 16 per cent. of NaOH used for No. I represents the minimum necessary to secure digestion. The addition of 2 per cent. excess in No. II is fully justified, the yield being nearly the same and the unit cost reduced by the lesser consumption of B. P. So also with 4 per cent. excess in No. III where the unit cost is still further reduced in spite of substantial fibre loss beginning to appear. With 6 per cent. excess in No. IV the economic limit has been passed, the fibre loss being more than the saving in B. P. is worth. It would therefore appear that a 4 per cent. excess added for bleaching effect is as much as economy will permit, and this conclusion is fully borne out by the whole series of digester tests which followed, the final average results being as under :—

TABLE VII.

Digestion results with NaOH in excess of amount required for resolution of non-cellulose : Crushed, starch-free bamboo.

TEMPERATURE, PRESSURE AND TIME AS PER TABLE VI.

—	NaOH.		Un-bleached yield.	B. P.		Bleached yield.	Unit cost.
	Per cent.	Tw.		(*a*) Per cent.	(*b*) Per cent.		
B. Tulda . . .	19½	11½	44·0	23	10·1	42·0	6·94
B. arundinacea . .	21	12½	43·0	25	10·8	40·8	7·23
B. polymorpha . .	19½	11½	45·5	25	11·4	43·0	6·82
C. pergracile . . .	20	12	44·5	23	10·2	42·3	6·73
Melocanna b. . . .	21½	13	43·0	27	11·6	41·0	7·42

(*a*) Per cent. on unbleached pulp.
(*b*) Per cent. on raw material.

The unit cost in each case is less than in Table VI and it is noticeable that the yields of the species are in closer agreement than the analytical results would lead us to expect, lending support to the supposition that if it were possible to accurately estimate the resistant α-cellulose, its quantity would be found to be practically the same for all species, the analytical variations being due to variable amounts of β-cellulose.

31. These results may be accepted as evidence that the soda process will prove satisfactory when digestion is aided by crushing the material and by extraction of the starch. When thus dealt with most of the causes of the variation hitherto found disappear, as does also the difficulty of the nodes, and all species and ages are brought down to so nearly a common level that the differences remaining can be dealt with by slight alterations in the digester conditions, amounting to not more than 2 per cent. of NaOH, 20 degrees of temperature and one hour in time. The one point open to objection is the bleach consumption which is undoubtedly high even under the conditions of Table VII, though not so high as to condemn the pulp, for its cost in this respect is more than compensated for by the cheapness of the raw material. It must also be remembered that the standard of colour to which the figures refer is a high one, higher than is necessary for most of the uses to which the pulp would be put. For common grades of printing paper, a consumption of one-half to one-third less would be sufficient. It is not likely that the pulp-maker in the tropics will be called upon to bleach his product; the paper-maker will prefer to do that himself as his requirements in colour vary with each description of paper he makes; but as the value of unbleached pulp depends largely on its bleaching capacity, the pulp-maker must necessarily keep that end in view and aim at producing not merely a well-digested clean pulp but one that will bleach easily and well. By the soda process, under the conditions specified above, he can do so *sufficiently* well. It now remains to be seen whether he can do it *better* by the sulphate method.

Sulphate process.

32. Sulphate liquor contains, as its active constituents, NaOH and Na_2S (sodium sulphide), the latter varying in amount from one-fifth to one-third of the whole. The actual digestion is, as with the soda process, done almost wholly by the NaOH, Na_2S having but slight saponifying effect on lignin. Its chief effect is to reduce the colouration products formed to compounds of a lighter colour and to hold them more perfectly in solution, so that they can be easily washed out without precipitation on the pulp. It therefore exercises a strong bleaching effect and the pulp produced is consequently lighter in colour and more easily bleached by B. P. It has also a retarding influence upon hydrolysis of fibre by NaOH and thus, to a slight extent, increases the yield. As the loss of soda is made up with sulphate of soda, which is a cheaper article than carbonate, the cost of chemicals is slightly less than for the soda process. The objection to it is the odour of sulphuretted hydrogen (the rotten egg smell), given off when discharg-

ing digesters, and it cannot therefore be recommended for practice in the neighbourhood of towns. But as pulp factories in India must necessarily be situated close to the areas from which the supply of raw material is drawn, that is to say, in sparsely populated localities, the objection will not have, as a rule, much force. The odour is not dangerous to health, merely disagreeable until one gets used to it.

33. As Na_2S has but small digestive effect, it can only to a small extent be substituted for the NaOH necessary for bare digestion as per Table VI, but it may usefully be used instead of the excess NaOH added for bleaching effect in Table VII. Its bleaching effect is so much greater than that of excess NaOH that it is desirable to use as much of it as circumstances will permit, provided the proportion of NaOH is not thereby reduced below the necessary amount, and the factor which chiefly controls the respective proportions is the efficiency of the soda recovery plant. Upon this depends the amount of sulphate added to make up for loss, and upon this again depends the respective proportions of hydroxide and sulphide in the final liquor. With a recovery of 80 to 85 per cent., these will usually average a ratio of 3 : 1, and our experiments have accordingly been made with liquor in this proportion. As the combining weights of NaOH and Na_2S are almost alike (40 and 39) the small error in calculating the whole in terms of NaOH may be neglected, and comparison with soda process results thus made easier. The following are the average results.

TABLE VIII.

Digestion results with sulphate liquor in which one-fourth of the NaOH is replaced by Na_2S : Crushed, starch-free bamboo.

TEMPERATURE, PRESSURE AND TIME AS PER TABLE VI.

——	NaOH and Na_2S calculated as NaOH.		Un-bleached yield.	B. P.		Bleached yield.	Unit cost. (c)
	Per cent.	Tw.		(a) Per cent.	(b) Per cent.		
B. Tulda	20½	12	45	16	7·20	43	5·86
B. arundinacea	22	12¾	44	17	7·48	42	6·22
B. polymorpha	20½	12	46	17	7·82	44	5·85
C. pergracile	21	12½	45	15½	6·97	43	5·87
Melocanna b.	22½	13½	44	18	7·92	42	6·36

(a) On unbleached pulp. (b) On raw material. (c) Unit cost of NaOH=4·5.

The quantity of combined chemicals required is 1 per cent. more than with straight soda liquor in order to maintain the minimum amount of NaOH necessary for digestion, but the extra cost of this is more than counterbalanced by the lesser cost of sulphate liquor, amounting to about Rs. 67 per ton of dry contents against Rs. 75 for soda liquor, its unit cost being 4·5 (bamboo = 1). The superiority of sulphate treatment is shown very markedly in the above table in the great reduction effected in bleaching cost, as also in a small gain in yield. The unbleached pulp is a light brown in colour, whereas that from the straight soda treatment is dark brown, and there is also an improvement in softness and in strength. For comparison of these results with those obtainable with *chipped* material *not* starch extracted, and with straight soda treatment the following may be quoted in the case of *B. polymorpha* :—

Chipped with nodes :—digestion quite impossible within an economic cost.

Chipped, nodes excluded :—NaOH 25 per cent., unbleached yield 42, B. P. 36 per cent. (=15·12 on raw material), bleached yield 39 per cent., unit cost 8·99.

As with the results in Table VII, the same remarks regarding bleaching (paragraph 31) apply to Table VIII, *i.e.*, the standard of colour is a brilliant white and the highest possible without serious loss of fibre by oxidation. A fair white suitable for many, and a good white suitable for most, of the uses to which it will be put can be obtained with 10 and 13 per cent. B. P. respectively. There can be no hesitation in declaring the sulphate method of treatment to be the best for bamboo both in cost and in quality of product. The high degree of purity of the product is attested by the following analysis in the unbleached condition :—

Mineral matter (ash)	1·68
Hydrocellulose (soluble in alkali)	4·37
Cellulose	91·64
Lignin (by difference)	2·31
	100·00

In unbleached sulphite wood pulp cellulose rarely reaches 89 per cent. and is frequently as low as 80 per cent.

SECTION D.

Microscopical.

34. The capillary tubes or pores alluded to in paragraph 5 (see also Plate II, *g*) which we have found to be so important a feature in

bamboo appear, in a microscopic cross-section, arranged in groups of four in the form of a rhomboid square. The groups are about 1 mm. distant from each other, and, in the groups, the tubes are about 0·5 mm. apart. Their diameter is 0·1 mm., mostly circular in shape though an occasional one is found of oval contour. None are flattened or collapsed. In old bamboo, one tube (occasionally two) in each group is wholly or partially filled up with infiltrated pectous matter. In a bamboo of three inches in diameter with walls half an inch in thickness there are about 8,000 of them. Each group forms a weak place in the tissue, which splits and breaks down under pressure, and, if the crushing is thoroughly done, it is possible to obtain fibre bundles with a cross-section diameter no greater than the distance between the groups, *i.e.*, 1 mm.

35. The individual or ultimate fibres strongly resemble those of straw in their appearance and colour reactions, which are blue with iodine and sulphuric acid, and violet with iodo-zinc-chloride. They are, however, nearly twice the average length of straw, and are, in the main, narrow and slender, and taper to fine points. About a fifth of the whole are from 0·6 to 1·2 mm. in length, the remainder being from 1·5 to 3·0 with a few running up to 4·0 mm. The proportion of short to long fibres is about the best possible for producing a closely woven well felted sheet of paper, and this quality is aided by their tapering pointed shape and their distinctively soft and silky texture and entire absence of harshness. Their dimensions for the five species are as per the following table :—

TABLE IX.

Dimensions of ultimate fibres (in mm.).

—	Length.			Diameter.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
B. Tulda	3·96	·70	2·60	·036	·009	·027
B. arundinacea	3·76	·60	2·40	·034	·008	·024
B. polymorpha	2·88	·60	2·45	·036	·009	·027
C. pergracile	3·87	·60	2·30	·027	·007	·020
Melocanna b.	2·90	·80	2·20	·022	·007	·018

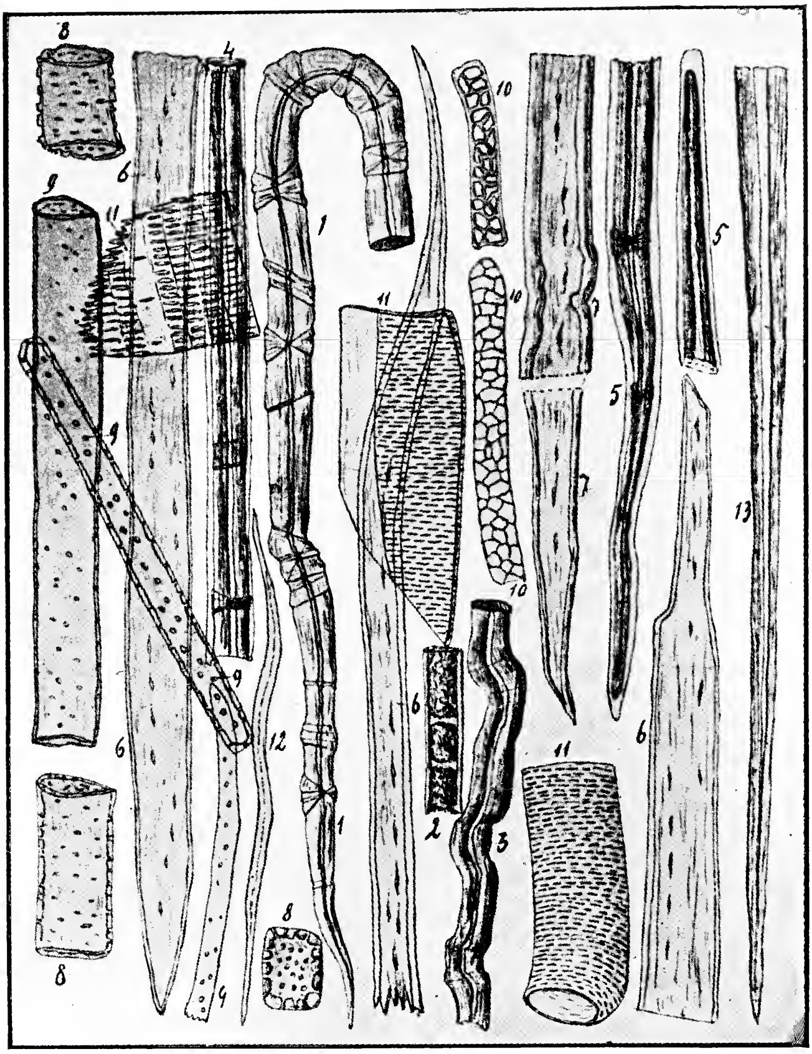

Photo-Mechl. Dept., Thomason College, Roorkee.

Bamboo-pulp made from *Cephalostachyum pergracile.*

1. Portion of fibre with end, without sheath, having displacements. 2. Fragment of a cell with characteristical content. 3. Portion of bent, curved fibre. 4. Middle portion with sheath. 5. End portion with sheath. 6. Broad thin-walled fibres with slanting slit pores. 7. Same with thicker wall. 8. Short parenchymatous cells having thick walls. 9. Long parenchymatous cells. 10. Net-like thickened elements. 11. Vessel and fragments of vessels. 12. Short sclerenchymatous fibre. 13. Long sclerenchymatous fibre.

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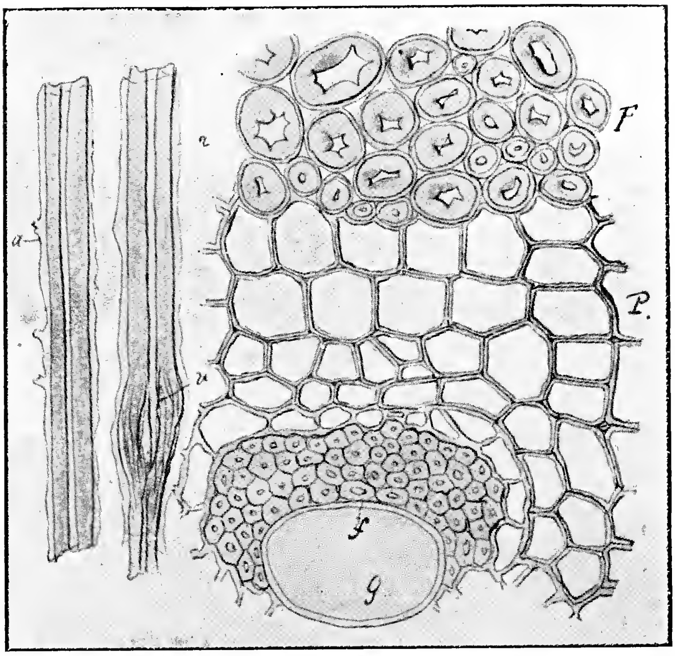

Fig. IIa. Fig. IIb.

Photo-Mechl. Dept., Thomason College, Roorkee.

Part of a section through the stem of *Cephalostachyum pergracile*. F. Large bunch of sclerenchyma fibres. P. Substructure tissue. *g*, large vessel ; *f*, the bunch of fibres adjacent to this.

Two portions of sclerenchyma fibres with envelope ; *a*, separated from the stem by boiling in potassium liquor ; *v*, displaced or squeezed part.

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36. By the courteous permission of the Editor of *Der Papier-Fabrikant*, Berlin, I am enabled to reproduce from that journal two microscopic illustrations and extracts from the report of Dr. Hanausek, the well-known technical microscopist of Vienna, upon specimens of bamboo (*C. pergracile*) and pulp made therefrom, sent to him by myself. The illustrations with their descriptive letterpress explain themselves. Dr. Hanausek's report contains the following :—

"The microscopic illustrations show two kinds of sclerenchymatous fibres, a short one 0·4 to 0·6 mm. long and about 0·009 broad, and a long one 1 to 2 mm. in length and about 0·02 broad. The fibres are spindle shaped and smooth, the ends pointed and not furcated (see Plate I, 12-13) ; the walls in the short fibres are highly thickened so that only a narrow lineshaped lumen remains ; in the long fibres the thickening is somewhat less and lumen distinctly visible as a stripe. The sample sent me by Mr. Raitt is bleached pure white, whilst formerly bleached bamboo has always retained a yellowish tint. On examining this sample under the microscope I found fibres which had a special sheath and also knots and displacements (Plate I, 1-5 and Plate II, *a*), and which have in general a striking similarity to those of the Japanese paper-mulberry (*Broussonetia papyrifera*). At first I imagined a mistake had been made in the description of the sample, but on obtaining from Mr. Raitt a sample of the raw bamboo (*Cephalostachyum pergracile*) I found the same kind of fibres in it. The above mentioned sheath has clearly not been noticed by botanists heretofore because it was destroyed when preparing the fibres. The sheath is present only in the long fibres (Plate II, F and *a*). The smaller fibres (Plate II, *f*) do not show it ; it renders it exceedingly difficult to distinguish between *Cephalostachyum* and *Broussonetia*, because the displacements, cross stripes and formation of knots are the same in both fibres. Besides the above mentioned two kinds of sclerenchymatous fibres, a third form of long cells occurs which possess no appreciable thickening but have slantingly truncated or pointed ends (Plate I, 6). These fibres are broader than the sclerenchymatous fibres and have one or two rows of oblique pores. These are numerous parenchymatous cells, either thin-walled and long (Plate I, 9) or thick-walled and short (Plate I, 8). There are no fragments of the epidermis in the sample sent me."

SECTION E.

General Conclusions.

37. It is not necessary for us to enter, at any length, into the question of the suitability of bamboo fibre for the manufacture of paper. This was fully demonstrated by Routledge 35 years ago, and again, in 1908, by Sindall in conjunction with Messrs. Thomas & Green, Ltd. (Soho Paper Mills, Wooburn, England). Every one who has handled the material has agreed that it is admirably adapted for the purpose and especially so for high class printing and illustration work requiring a close even texture and surface, and a minimum of stretch and shrinkage under the damping operation. The one serious objection hitherto made has been the cost of bleaching. With the soda process, no matter whether the bleaching is accomplished by a large excess of NaOH and a small excess of B. P. or *vice versâ,* the cost is nearly, though not quite, prohibitive. As we have seen, the application of sulphate treatment removes this difficulty and brings the bleaching expenditure down to a figure which compares favourably with that of any of the raw materials now in use.

38. My conclusions as to the unsuitability of the sulphite process agree with those of Richmond. In regard to the soda method, when allowance is made for differences in preliminary treatment (*e.g.*, crushing and starch extraction and inclusion of nodes) my results are in fair agreement with those of both Sindall and Richmond so far as digestion is concerned. In the final test of bleached colour no comparison is possible in the absence of any recognised standard of whiteness. As regards the sulphate method of treatment, this has never before been applied to bamboo, thus no data are available with which to compare the results I have arrived at.

39. The questions asked at the outset of this enquiry and detailed in paragraph 3 may be answered as follows :—

(*a*) All five species are suitable for the manufacture of cellulose at a marketable cost, assuming that they can be delivered to mill sites at a cost not exceeding Rs. 15 per ton of air-dry bamboo.

(*b*) Culms of all ages may be mixed indiscriminately in treatment.

(*c*) Nodes need not be rejected.

(*d*) If required, all the species mentioned except *Melocanna* may be mixed in treatment.

The serious and special difficulties hitherto experienced with bamboo, *viz.*, irreducible nodes, irregular yields, irregular digestion of mixed ages

and high cost of bleaching, can all be overcome by the adoption of the following treatment :—

(*a*) Culms not to be cut until the shoots of the year are full grown.
(*b*) A period of seasoning of not less than three months to elapse before they are used.
(*c*) Crushing.
(*d*) Extraction of starchy matter.
(*e*) Digestion with sulphate liquor.

The adoption of this scheme of treatment not only gets rid of the special difficulties above mentioned, but also brings all five species to so nearly a common level that pulp of excellent quality can be produced from any of them by treatment of which the extreme variations need not exceed limits of 20 to 22 per cent. NaOH (inclusive of Na_2S), temperatures of 162° to 177°, pressures of 80 to 120 lbs. and duration of digestion 5 to 6 hours.

Cost.

40. In attempting to form an approximate estimate of the cost at which such pulp can be produced, the paramount importance of site and freight facilities must be strongly insisted on. The total amount of inward and outward freightage per ton of product is approximately 6 tons, made up as follows :—Coal 2 tons, bamboo $2\frac{1}{4}$, lime and soda $\frac{1}{2}$, sundries $\frac{1}{4}$, and pulp 1 ton. Therefore, if freight cost averages only Rs. 5 per ton, it amounts to Rs. 30 on an article worth approximately Rs. 125. It will be understood from this that any estimate based on a factory site where the freight conditions are not accurately known would be of very little value. Of all the localities enquired into by the Forest Economist, the neighbourhood of Rangoon is the one which offers the greatest amount of certainty and the least amount of speculation on this point and I shall therefore base my estimate upon a site there, and assume that it has the advantages of rail, river and sea transportation, and that a plant capable of producing 200 tons per week of unbleached pulp is erected. This selection does not imply any adverse reflection upon the other localities reported on by the Economist, and I would point out the possibility of some of them having advantages in other respects to counterbalance any transport disadvantages, should such exist. Thus, in South Malabar the estimated cost of bamboo delivered at factory site is only Rs. 4 per ton against Rs. 10 at Rangoon, a difference which means Rs. 13-8 per ton of pulp. Again, a site nearer to a coal supply might easily be equivalent (assuming equal advantages in other respects) to a reduction of Rs. 15 to Rs. 20 per ton of pulp.

41. The Economist's estimate for air-dry *B. polymorpha* and *C. pergracile* delivered at such a site is Rs. 10 per ton. To this I add 25 per cent. to cover the rise in cost which is likely to occur soon after the establishment of a large new demand. This brings it to Rs. 12-8, and according to Table VIII, with an average yield from these two species of $45\frac{1}{2}$ per cent., the quantity required for one ton of pulp is 43·94 cwts.—say 44 cwts. which will cost Rs. 27-8.

42. The cost of chemicals depends largely upon the efficiency of the recovery plant which, if of the quadruple effect vacuum system, would cost approximately £8,000 complete with buildings. In accordance with the usual factory practice, I estimate the cost of the regenerated liquor which it would deliver to the mill proper as if the chemical plant was a separate department bearing its own charges for materials, depreciation, repairs and labour, but not superintendence. The percentage of recovery I take at 85 per cent. of the total consumption of soda ; 90 per cent. is possible and is frequently obtained, but the considerable amount of silica in bamboo would have the effect of slightly lowering this efficiency. Lime is quoted in the Economist's report as costing 5 annas per cubic foot delivered, which is equal to about Rs. 14 per ton. Sulphate of soda (crude salt cake) can, I find, be imported and delivered for about Rs. 55 per ton. Coal from Bengal I take at Rs. 15 per ton, which appears to have been about the average of the last three years. At these prices and taking labour at current local rates and including a charge of £800 per annum (10 per cent. on capital cost of plant) for repairs and depreciation, I estimate that the finished sulphate liquor could be prepared at a cost equal to Rs. 65·8 per ton of active dry contents reckoned as NaOH of 76 per cent. strength. The average quantity required according to Table VIII is 9 cwts. 0 qrs. 14 lbs. per ton of pulp, which would therefore cost Rs. 29-14.

43. The data available for estimating the cost of labour and superintendence is limited to the experience of wood and straw pulp manufacture in Europe, and of paper manufacture in India. Neither is very applicable to the matter in hand. In the former, the cost is that of highly paid white labour of high efficiency, whereas we have to deal with cheap native labour of low efficiency, with its cheapness counterbalanced to some extent by the higher cost of imported superintendence. The experience of Indian paper mills does not help us much, because the labour cost of pulp-making is very much less than that of paper-making, but it gives us some idea of the relative efficiency of European and Indian labour engaged on somewhat similar work. With an item thus open to some

amount of uncertainty the only safe rule is to frame an estimate which may prove in actual practice to be somewhat high. I would therefore put the charge for native labour and imported superintendence at Rs. 7 per ton. This figure is based mainly on a knowledge of what can be done in European factories translated into terms of native labour efficiency, with its lower cost qualified by the higher expenditure on imported superintendence. Should it prove to be wrong, I shall expect it to be somewhat too high. It does not include labour on the chemical plant, that having been estimated for in its own department.

44. Fuel is a somewhat serious item as it would be necessary to use coal imported from Bengal. The power required in a pulp factory is not large, an installation of 500 to 600 I. H. P. being sufficient for an output of 200 tons per week. The total amount of fuel required for all purposes, making ample allowance for the low calorific value of Bengal coal, would be about 2 tons per ton of pulp. 17 cwts. of this will be used by the chemical plant and has already been included in the estimate for that department. Of the remainder about 15 cwts. is required for pulp digestion and drying, and 8 cwts. for power. At Rs. 15 per ton the cost will be Rs. 17-4 per ton of pulp. In districts where firewood is available or coalfields are near, this item is capable of considerable reduction, but the proportion of it actually used for power does not invest the question of waterpower with much importance, unless it can be obtained without sacrificing other advantages.

45. The whole manufacturing plant and buildings will cost approximately £50,000 of which £8,000 is absorbed by the chemical plant and for which provision has already been made for depreciation and repairs. A similar charge on the balance expended on the mill proper, *viz.*, 10 per cent. per annum, amounts to Rs. 6-5 per ton of pulp. Other charges to be considered are Government royalty Re. 1, and insurance, taxes, mill stores, and sundry and petty charges Rs. 3-9 per ton.

46. We thus arrive at an estimated cost per ton of unbleached pulp as under :—

	Rs.	A.	P.	
Bamboo	27	8	0	
Chemicals	29	14	0	
Fuel	17	4	0	
Labour and superintendence	7	0	0	
Depreciation and repairs	6	5	0	
Royalty	1	0	0	
Insurance, taxes, stores and sundries	3	9	0	
	92	8	0	or say

£6-3-4 per ton of 2,240 lbs.

Should it be necessary to produce a bleached pulp, the cost will be, for a fully bleached article, Rs. 125 per ton, inclusive of the loss in weight caused by bleaching.

47. I am aware that estimates have been framed putting the cost of unbleached pulp by the soda process with nodes excluded as low as from £4-18-0 to £5-10-0. By the sulphate method these would be reduced to £4-14-0 and £5-6-0. I am unable now to accept anything as low as these in spite of the economy gained by utilising the nodes and would point out that the data given in the Economist's report, as well as the comparatively recent general rise in prices, entails a considerable recasting of figures which might have been accepted before the former was available or the latter occurred. At the same time, my estimate is a conservative one and, in practice, I would expect to see it somewhat reduced. As it stands it is quite satisfactory, especially when it is remembered that it represents a pulp which can be bleached at a cost which is at least Rs. 15 per ton less than for the soda pulp represented by the above mentioned low estimates. Its first market would probably be Calcutta with a strong probability of an export to China and Japan. The present landed prices of European wood pulp may be taken as follows :—

Unbleached, Calcutta, Rs. 147. Bleached Rs. 173 per ton.
Unbleached, China and Japan ports, Rs. 167. Bleached Rs. 193 per ton.

Bamboo pulp from Rangoon could be landed at :—

Unbleached, Calcutta, Rs. 100. Bleached Rs. 132-8 per ton.
Unbleached, China and Japan ports, Rs. 118. Bleached Rs. 150-8 per ton.

The margin is ample for both competition and profit.

48. Regarding the probable amount of trade which can be done, the following remarks may be of interest. The present annual consumption of paper in India and Burma is estimated at from 60,000 to 70,000 tons and is rapidly expanding in response to the growth of education. Of this, not more than 25,000 tons are manufactured in the country and no extension is possible until a better supply of raw material is assured. The local mills have long since reached the limits of economic radius from which they can draw supplies in the raw state, a state which means freight and handling charges on 2½ tons of material for each ton of product, and rather than extend this radius further, it suits them to import European wood pulp to the amount of 8,000 tons per annum at a high cost for freight. To put the Indian paper industry on a satisfactory basis its system must be revolutionised on similar lines to the change of methods which has taken place in Europe, *i.e.*, the raw material must be partly manufactured

at or near the source of supply and the 50 to 60 per cent. of waste there got rid of. With the industry thus divided into pulp-making and paper-making proper, the future expansion of the latter is assured, and the extraordinary anomaly of a country teeming with raw materials and having good natural facilities for manufacturing them, and yet unable not only to supply its own demand for the manufactured article, but actually having to import partially manufactured material with which to produce the small amount that it does make, will cease. Besides the present local demand and the large expansion of it which may be expected as soon as our paper mills are in a position to undertake it, there is a rapidly growing market in China and Japan which may be tapped, and which is represented by a present annual import of 30,000 tons of European wood pulp, and on which there is, to pulp manufactured in India, what amounts to practically a bonus of Rs. 15 per ton in difference of freights. Further, in view of the admitted increasing scarcity of Spruce wood and the gradually increasing cost of wood pulp it does not appear to be beyond the bounds of possibility to see an export trade to Europe develope. The *primâ facie* grounds for such a prospect are, firstly, the cost of raw wood to produce 1 ton of pulp, which now amounts to from £3-0-0 to £4-10-0 and may be expected to increase, against which we have bamboo costing from 15 shillings per ton of pulp in Malabar to £1-16-8 at Rangoon, which figures are 25 per cent. in advance of present estimated costs: secondly, the fact that, owing to the rapid natural reproduction of bamboo, a mill will have a supply *in perpetuum* at its own doors, whereas in the case of wood pulp, a mill which may originally have had its supplies close at hand is compelled every year to go further back into the forests for them at an ever-increasing cost for transport, a cost which in from ten to twenty years becomes prohibitive and compels the factory either to shut down or to be removed to a fresh site.

49. In conclusion I have to gratefully acknowledge the advice and assistance I have had in the preparation of this report in its economic aspects from the Forest Economist, R. S. Pearson, Esq., and upon the botanical questions involved from the Forest Botanist, R. S. Hole, Esq., and in the determination of specific gravities and the checking of estimations and results from the Forest Chemist, Mr. Puran Singh, F.C.S.

INDIAN FOREST RECORDS.

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Note on the Preparation of Tannin Extracts with special reference to those prepared from the bark of Mangrove (*Rhizophora mucronata*).

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INTRODUCTION.

UNDER instructions of the Inspector-General of Forests conveyed in his letter No. 1381—79-6, dated 15th August 1908, an investigation into the causes of the objectionable colour of the Mangrove bark extract as prepared at the Government Tannin Factory, Rangoon, has been carried out by the writer mostly at the Government Tannin Factory, with a view to eliminate, if possible, the colouring matter complained of, and to form an idea as to the probable commercial prospects of the industry of tannin extract manufacture in Burma, chiefly from Mangrove barks.

This note embodies a brief *résumé* of the general processes of tannin extract manufacture and the factors which influence the manufacture of good extracts, together with a valuation of the Mangrove barks as raw materials for tannin extracts. It also discusses the commercial prospects of this industry in Burma where a large supply of the raw material can be made available from Tavoy, Mergui and Andaman Isles.

In Chapter I of this note, a general description of the processes of tannin extract manufacture is given in order to give an idea of the

theory of preparing tannin extracts. The processes are described under the heads of (1) Extraction, (2) Cooling, (3) Filtration or Mechanical clarification, (4) Evaporation, (5) Decolourisation and (6) Mixed Extracts. Under the latter head " Mixed Extracts," arguments have been advanced to show, that in tropical countries at least, where forests abound in tanning materials of all kinds, the manufacture of mixed extracts is preferable to that of decolourised extracts.

Chapter II deals with the factors that determine the quality of tannin extracts specially with reference to that from Mangrove bark. It has been shown that use of fresh bark or air-dried fresh bark, and of distilled water for leaching the bark, is essential, and that, after extraction, the cooling of the tan liquors and their mechanical clarification are necessary processes that cannot be dispensed with if a good quality of extract is desired.

Chapter III gives a summary of the defects in the extracts that have been from time to time manufactured experimentally in Burma. The commercial valuation of the tannin extract prepared by the writer on a large scale is also given to indicate the possibility of making a marketable extract from the Burma barks.

Chapter IV deals with the percentage yields of the tannin extract from Mangrove barks of different species, with a conclusion that the air-dried barks of good quality should yield 50 per cent. of extract containing 20 per cent. moisture.

The estimates of the capital outlay required for a model tannin extract factory together with an analysis of profit and loss of the manufacture of Mangrove tannin extract are given in Chapter V. With an outlay of ₨2,86,500 on a factory dealing with 60 tons of the raw material per day, there is likelihood of a net profit of 27 per cent. being obtained on the total capital outlay, where good tannin extracts made from myrabolams and Mangrove barks mixed in proportion of 1 : 6 are produced. The possibility of making a small concern with an output of 1½ tons of extract per day, remunerative, has also been noted, the figures being based on those actually obtained by the writer in experimental manufacture on this scale.

This note is published in the hope of creating an interest in an industry of a comparatively recent growth even in Europe. A statement of the development of trade in the tannin extracts together with a list of firms dealing in tannin extracts machinery is appended.

The writer desires to take this opportunity of expressing his best thanks to Professor W. R. Dunstan of the Imperial Institute, London, Dr. Gordon Parker of the Leather Trades Laboratories, London, Professor W. R. Procter of Leeds University, and Messrs. C. Rogers, Conservator of Forests, Pegu Circle, and H. B. Anthony, Divisional Forest Officer, Depôt and Agency Division, Rangoon, for the help received from them in this investigation.

CHAPTER I.

A *Résumé* of the Process of Tannin Extract Manufacture.

The principle of the manufacture of Tannin Extract is very simple. The tan wood or bark is reduced to a form suited for extraction by means of special machinery adapted to the requirements of the material treated, and the extract is then evaporated in vacuum pans to a solid form.

Extraction.—The extraction is carried out in the open, using either a system of wooden vats, or under pressure in a battery of closed copper autoclaves. The latter seem to possess little advantage over the former except that they offer facilities for extraction on a very large scale. According to the experience of tannin extract manufacturers, the "leach-ing" of the material in open wooden or copper vats gives better results than close autoclaves under pressure. The following advantages have been indicated by Messrs. Dumsney and Noyer [1] in favour of open wooden vats:—

(1) The quantity of steam required is not more, if not less, than what is required for a battery of autoclaves.

(2) The battery of wooden vats is absolutely safe.

(3) The initial cost of putting in a battery of wooden vats is lower and such requires less repair than a battery of autoclaves, where the pressure of the liquid demands special and costly piping which is soon liable to leak.

(4) The management of a battery of wooden vats is simpler and more systematical.

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[1] See Wood Products, Distillates and Extracts by P. Dumesny and J. Noyer, p. 185.

(5) The percentage yield of the extract obtained from wooden vats is equal, if not superior, to that furnished by a battery of autoclaves.

(6) In open vats even if the tan liquor is heated to 100°C, it develops less colour and contains less insolubles, and consequently is more quickly clarified and more readily decolourised than in the case of tan liquors extracted under the pressure entailed by the use of autoclaves. In autoclaves the non-tannins increase with the pressure owing to the transformation of tannin into non-tannin, and to the solution in the tan liquor of the non-tannins which are rendered soluble through hydration.

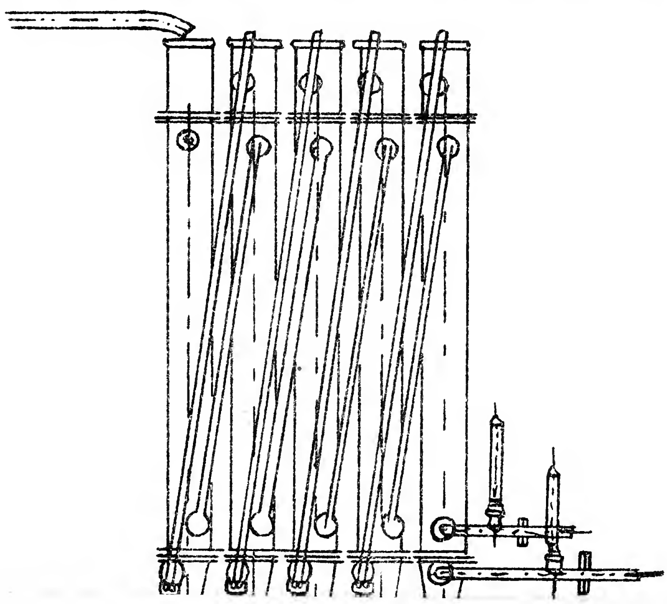
(7) The open system of vats yields extracts containing a higher percentage of tannin than those obtained by using autoclaves wherein the temperature rises to 127°C, this high temperature undoubtedly destroying an appreciable quantity of tannin.

The "leaching" is done at different temperatures according to the material treated, but generally a temperature of 70° to 80°C is high enough. To extract all the available tannin, the material should be leached seven times. The number of leaches may be reduced in the case of materials not very rich in tannin and of those that yield their tannin without difficulty under the action of water, but experience has shown that rich materials like Mangrove barks and myrabolams have to be leached seven times.

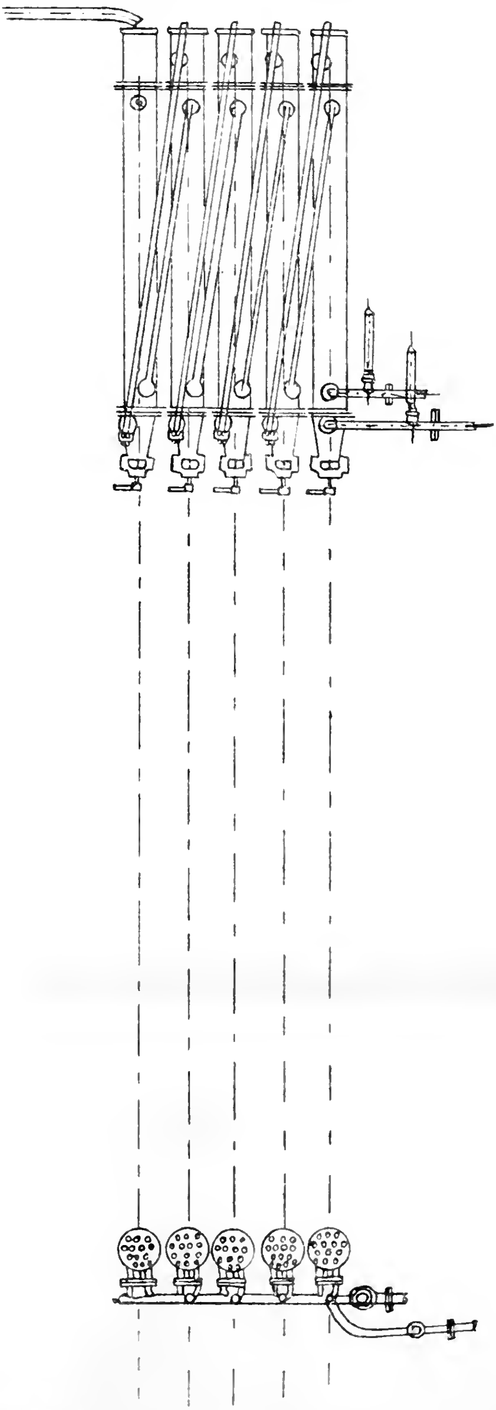
The tan liquors are concentrated by passing them through a series of wooden vats filled with the raw material till they show a Sp. Gr. of 9° to 11°B. The concentrated liquors thus obtained are next transferred to a large tank made of wood or copper—the so-called "liquor tank." This tank is kept on a higher level so as to allow the liquor to flow to the refrigerators by gravity.

Cooling.—A very important step in the manufacture of tannin extracts is the cooling of tan liquors below 18°C. In practice the temperature should be reduced to 15° to 18°C and should never be allowed to exceed the latter limit. For this purpose, based on the latest experience, tubular refrigerators are recommended as the most suitable (see Plate I). These refrigerators are vertical and consist of five "elements" with tubular bundles. Their interior condensing surface is

TUBULAR REFRIGERATOR



TUBULAR REFRIGERATOR



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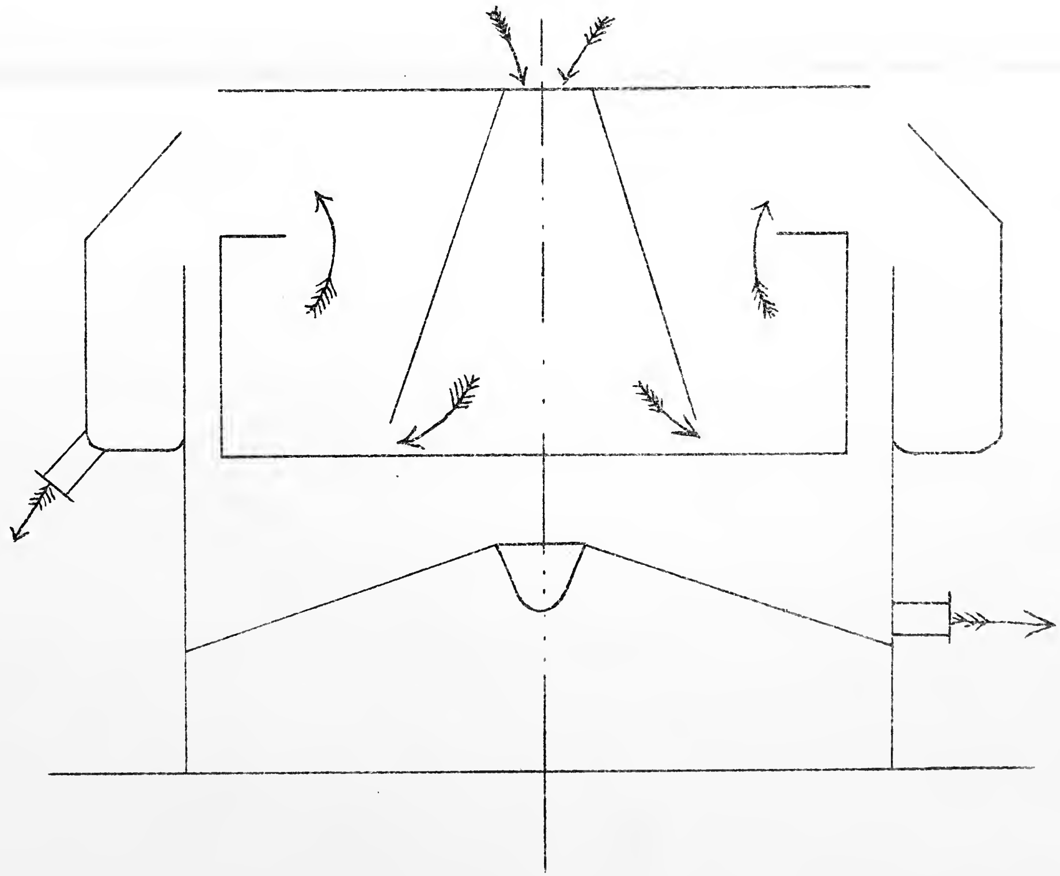
DECANTING CENTRIFUGAL.



Zinco., November, 1911.—No. 8429-1-1100

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calculated according to the quantity of tan liquors to be cooled from 100°C to $\underline{n}$ degrees ($\underline{n}$ being the temperature of the cold water used in the factory). According to the calculations of Messrs. Dumsney and Noyer the condensing surface required per ton of liquor at 100°C to be cooled from 100° to 20°C is 1·2 to 1·5 sq. metres.

Filtration.—The artificial cooling of the tan liquors as given above has a marked effect on their clarification. Most of the insoluble "reds" or "phlobaphene," pectosic and resinoid bodies are precipitated out. The next step, therefore, for completing the clarification is to rapidly filter them through filter presses or decanting centrifugals. The filter presses best suited for this purpose are those with 13 chambers having 12 interposed wooden frames of 13½ in. square. One filter press of this kind would give 22 gallons of clear filtrate per hour. In this process, pasty cakes consisting of wooden dust, pectosic and resinoid bodies, etc., are formed which fill the interposed space. The liquors thus treated are freed from a large amount of insoluble matter.

Mechanical Clarification.—Finding that filter presses are too slow and too costly in their action, the extract manufacturers prefer to employ only decanting vats. These are large vats in which the liquors are allowed to stand and deposit their insolubles. The latest improvement, however, consists in the use of decanting centrifugals. A form of the decanting centrifugal is given in Plate II. In this centrifugal, the formation of "cakes" takes place on the circumference of the copper basket of the centrifugal and the clarified liquor is decanted in a continuous jet from the upper portion of the basket. The advantage of this method can at once be seen from the fact that for clarifying 19,800 gallons in 24 hours, one requires a decantation battery of 110,000 gallons capacity, while four decanting centrifugals of 1·2 metres diameter will do the same work. The decanting battery would require 300 sq. metres of surface instead of 30 sq. metres required by these centrifugals. The centrifugals can be installed at less than half the cost of huge decanting batteries. It is, therefore, recommended that in place of filter presses and decanting batteries, decanting centrifugals made by *Robatel Buffaud & Co., Lyons, France,* can be used with great advantage and economy. A factory treating 60 tons of wood with liquor amounting to 20,000 gallons in 24 hours would require only four decanting appliances costing £640.

Evaporation.—The mechanically clarified liquors are then evaporated

in vacuum pans into solid extracts. This is done in four ways, (1) by Simple effect system, (2) by Double effect system, (3) by Triple effect system and (4) by Kestner's system.

Simple Effect Vacuum Pan.—This consists of a closed pan made of copper or bronze in which the pressure is reduced by connecting it with the suction of a vacuum pump. Its shape is like that of the left-hand pan shown in Plate III.

The "calandria" of the Simple effect pan is provided with two horizontal tubular bronze plates pierced with holes in which are fixed the tubes of a tubular bundle, whereby is formed a large heating surface. The tubular bundles are surrounded by a heating chamber wherein is introduced the steam from the boiler to evaporate the liquors which are passing through the tubes. Thus steam coming into the heating chamber condenses and gives up its latent heat to the tan liquors to be evaporated. The tan liquors then begin to boil under reduced pressure and thus yield a fresh amount of steam. The water condensed in the heating chamber is run off to feed the boiler. The steam from the boiling liquor is condensed in a surface condenser placed in front of the air pump at the exit from the pan. This device yields a corresponding quantity of condensed water which is used for extracting the material, while with a barometric or with an injection condenser, the steam mixed with the condensation water runs down the drain in sheer waste. The use of a surface condenser is, therefore, recommended in order to collect the distilled water from the boiling tan liquors for use in extraction without any extra cost. It may be pointed out here that the best results in tannin extract manufacture can only be obtained by *the use of pure water*. The condensed water from the evaporating vessels must be used for extraction purposes, and should surface condensers as mentioned above not be used, a special pump called the "condensed water pump" is required to collect it.

Double Effect System.—This type of vacuum pans consists of two pans communicating with each other in which the pressure is reduced at the exit of the second pan. The heating system is as in the Simple effect system with this difference, that the quantity of steam generated by boiling the liquor in the first pan is utilised to heat the tubular bundle of the second vessel and to boil the liquors therein. The steam rising from the boiling liquors of the second pan is then collected by surface condensers from which it is pumped to the condensed water reservoir

TRIPLE EFFECT PLANT

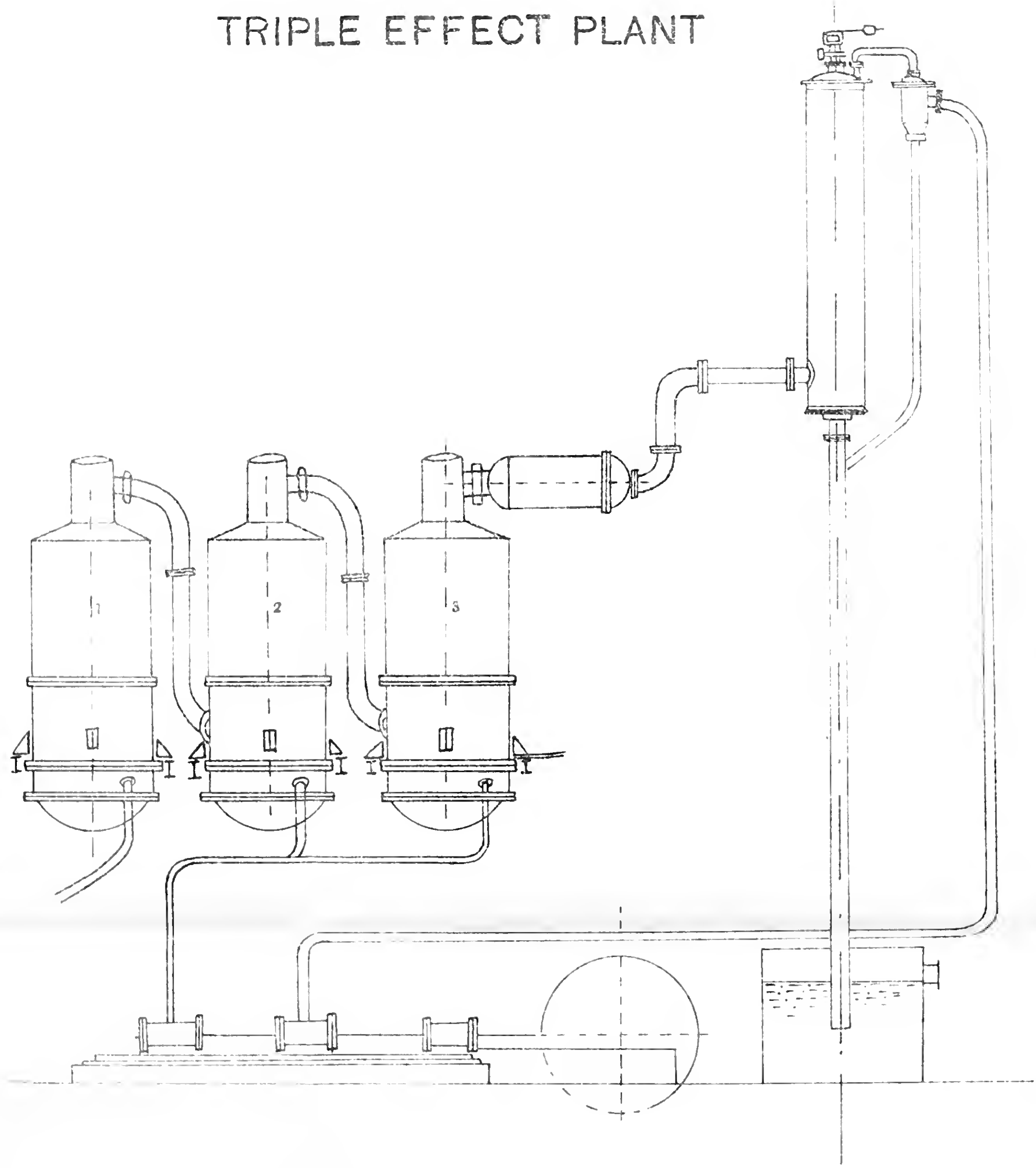

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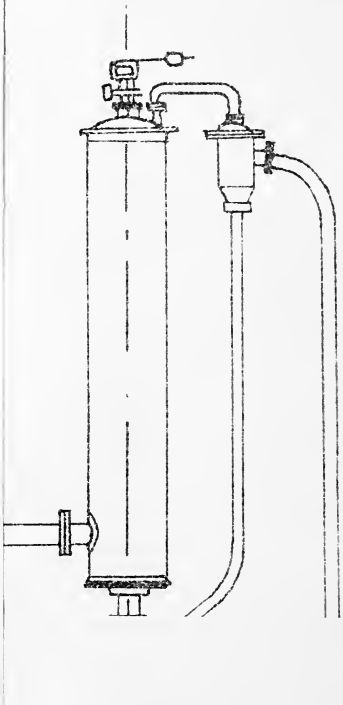
Plate III.



which feeds the extraction vats. The general shape of this system of pans is similar to the Triple Effect System described in Plate III, except that it has two pans instead of three.

Triple Effect System. (See Plate III.)—This, consisting of three pans instead of two as in the Double effect system, is in general use in tanning factories. It ensures constant and economical working by its great evaporative capacity coupled with minimum consumption of steam. In the first pan the vacuum usually is 35-40 cm., in the second 50-56 cm., and in the third 60-69 cm., making the liquors boil at 84°C in the first, at 73°C in the second, at 54°C in the third. Thus 1 kilogramme of steam at 100°C entering pan No. 1 produces 1 kilogramme of water at 84°C and 1·015 kilogrammes of steam from the tan liquors in No. 1, which in turn is converted into 1 kilogramme of condensed water at 73°C and 1·05 kilogrammes of steam from the tan liquors in No. 2, which in turn condenses into 1·05 kilogramme of water at 54°C producing 1·125 kilogrammes of steam from tan liquors in No. 3. The steam from the tan liquors in No. 3 finally goes to the surface condensers for collection. Thus with 1 kilogramme of steam which in the Simple Effect System could only evaporate 1·015 kilogrammes of water, a total of 3·19 kilogrammes of water has been evaporated in the Triple Effect System.

Kestner's Evaporator.—The improvements in tanning extraction machinery are being effected very rapidly, and lately the Triple Effect System has been replaced by another still more efficient evaporator called Kestner's evaporator. This plant consists of a tubular bundle 7 metres in length and is constructed with simple, double, triple, and multiple effect to be heated either by the live steam from the boiler or escape steam from the engines. These evaporators occupy a very small space and are of simple construction, and having few joints they are unlikely to leak. They have another great advantage that they can be easily cleaned, allowing them to maintain their maximum capacity of output unimpaired. The liquor is equally distributed by a special arrangement through all the tubes of the bundle, which, it may be pointed out here, is a great advantage from the point of view of possible damage to products like tanning extracts owing to their being sensitive to heat. The difference is somewhat marked compared with other systems, thus for two sets of plants doing the same work, the ordinary quadruple effect would contain 15,000 litres in concentration while Kestner's plant would have only 500. This difference indicates the application of a new principle in the construction

of this evaporator. The liquid rises through a tube 7 metres long, by a phenomenon called *grimpage* or "climbing." The ratio between the volume of the liquid that passes up the tube from bottom to top and the volume of steam which escapes from the top has been calculated to be 1 : 1,000.

Globules are formed in the bottom of the tube, and the liquid begins to rise in thin layer up the sides of the tube under the action of the steam. The steam keeps on circulating at a speed of 25 metres per second. Under these conditions, the evaporation is very intensive and the tan liquors are placed under conditions best suited to prevent the extract being damaged. Practical experience has also shown that the employment of Kestner's evaporators has always yielded a superior product. The superior efficiency of this plant has been proved beyond doubt.

Different Processes of Decolourisation.

Since 1879, a long series of patents has been taken out, and it is not possible to describe all the processes of decolourisation here. It is only proposed to glance at the available literature on the subject. The chief decolourising materials are (1) sulphurous acid, or bisulphites, (2) blood or albumen, (3) oxalic acid and alumina, (4) animal charcoal, (5) haloid salts of organic acids, (6) sulphurous acid gas under pressure, (7) aluminium hyposulphite, (8) barium chloride, (9) lead nitrate, (10) lactic acid, etc. All the chemical processes of decolourisation, however, entail some loss of tannin, and some of them also affect injuriously the quality of the extracts. For example, the clarification of tan liquors with blood which is one of the most rational processes causes a loss of 10 per cent. of tannin in the extract. The nitrate process is still less to be recommended because the eventual formation of free nitric acid destroys a considerable amount of tannin owing to secondary reactions.

A satisfactory process of decolourising the tan liquor has been patented by George Klenk (English patent 25,063, December 1901). This process[1] consists in the addition of aluminium sulphate and sodium bisulphite as follows :—

Add to the hot tan liquors in a vat fitted with an agitator a solution of sulphate of alumina, and after the mixture of these two liquors, add thereto bisulphite of soda (38° to 40°B), stirring constantly. The average proportions used are 8·8 lbs. of aluminium sulphate and 33 to 40 lbs,

[1] See Jour. Soc. Chem. Ind., Vol. XXI, 1902, p. 1462.

sodium bisulphite to 1,100 gallons of liquor at 4°B. The liquors so treated are decolourised by aluminium hydrate in nascent state, which agglutinates the resinoid particles of the liquor and falls with them to the bottom of the vat just like blood or albumen. Moreover the nascent sulphurous acid as it escapes during the reaction has an intensive decolourising effect. Extracts thus made are soluble in cold water and retain an acid reaction.

Sodium bisulphite forms the subject of various patents. In one of the patents the tannin extracts are treated with sulphurous acids, sulphites, bisulphites and hyposulphites, and also with a mixture of hypophosphorous acid and phosphorous acid, by means of which reduction and decolourisation takes place.[1]

In another process [2] milk, preferably butter milk, is added to the tannin extract and the mixture heated to 70°C. The albumen of the milk is thus coagulated and while settling, it takes with it the insoluble matter and part of the colouring matter of extract.

Another patent [3] consists in the use of formaldehyde sulphoxylate, either pure or mixed, with formaldehyde bisulphite. For example, one litre of chestnut extract of 4°B is treated with about 5 gram of *Rongalite C.* (sodium formaldehyde sulphoxylate of about 90 per cent. strength), and evaporated to dryness in a vacuum.

The writer while first trying his laboratory experiments on the decolourisation of Mangrove bark in 1908, thought of utilising nascent hydrogen as a decolouriser of Mangrove bark tannin extract and, accordingly, he tried the effect of extracting the bark in contact with metals and weak acids such as tin, and zinc in contact with acetic, oxalic, formic acids, etc. A considerable improvement in the colour of the extract was observed. Acetic acid, however, had a bad effect on the tannin strength. Lactic acid and oxalic acids in small quantities were, therefore, preferred. Much of the effect and the reduction of the deep colour of the extract was due to the presence of free organic acids. It was also noticed that the contact of the metals tin and zinc with the bark while under treatment, even without the presence of free organic acids, produces an appreciable reduction in the colour of the resulting extract. This has been

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[1] See Jour. Soc. Chem. Ind., Vol. XXVI, 1907, p. 704.

[2] *Loc. cit.*, Vol. XXVIII, 1909, p. 804.

[3] *Loc. cit.*, Vol. XV, 1906, p. 770.

previously noticed and the use of tin, zinc and aluminium in the extraction was patented as far back as 1902.

Another patent [1] consists in subjecting the tannin extracts during preparation to the action of electricity with alternative currents, using electrodes of aluminium, tin and zinc.

Another patent,[2] on the principle of using nascent hydroxides and hydrogen, was taken out in October 1909. In this patent tannin extracts, more particularly Mangrove tannin extracts, are decolourised by means of nascent hydroxides of metals produced by electrolysis in a bath having different metals as anode and kathode, solutions of the salts of these metals being also added to the bath. The precipitated hydroxides carry down the colouring matter in the form of a lake while nascent hydrogen has also a clarifying effect; aluminium and zinc are most suitable metals for the electrodes.

For the treatment of Mangrove bark, malletto bark and Quebracho wood, the use of "activated aluminium"[3] has been recommended. "The activated aluminium" (prepared by treating it with caustic alkali solution and rinsing it with water and then treating it with mercury chloride and again washing) is well mixed with tannin extracts, which are agitated and allowed to cool and settle, after which they are concentrated. The leather made with the extracts thus treated becomes but little darker under the action of light, and is free from the red shade usually characteristic of leather prepared by using untreated extracts.

It will be gathered from the above that a great variety of processes has been devised and various patents have been taken out for the decolourising of the tannin extracts. It seems that almost the whole field of original research on the subject has been covered. But the writer has employed a method for the decolourisation of dark and red coloured tannin extracts which, as far as he is aware, has not yet been adopted. This method consists in the use, in small quantities, of freshly precipitated nickel hydroxide for the fractional precipitation of the tan liquors, which takes up most of the colouring matter and impurities and settles down as a precipitate, from which it can be recovered and used over and over again. He hopes to revert to the subject in a future publication,

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1 Jour. Soc. Chem. Ind., Vol. XXI, 1902, p. 1462.

2 *Loc. cit.*, Vol. XXIX, 1910, p. 365.

3 *Loc. cit.*, Vol. XXVIII, 1909, p. 1321.

setting forth the commercial possibilities of the process. It may be pointed out here that though the decolourisation by nickel hydroxide entails some loss in the percentage of tannin which in chemical processes is always inevitable, yet it has no injurious effect on the original properties of the material. In this respect, the process combines in itself the effects of chemical decolourisation and mechanical clarification. This is an advantage, which very few processes of chemical decolourisation possess.

Considering the necessary defects that chemical treatment of the tannin extract entails, the latest view on the subject is that the processes of decolourisation by chemicals are quite inconsistent with manufacture of good extracts. The authoritative opinion of Messrs. Dumsney and Noyer on this point may be quoted here: "The decolourisation of the future does not lie in the use of chemical products, nor more or less complicated processes; tanning is an industry already far too complex to stand it; it requires and will require, before and above all, pure extracts of a well-determined nature, with a high percentage of tannin, soluble in cold water and finally of as constant and uniform a composition as possible." (*Wood Products, Distillates and Extracts* by P. Dumsney and J. Noyer, page 205.) The same authors (*loc. cit.*, page 206) commenting upon a process of decolourisation based on the use of aluminium sulphate and sodium bisulphite make the following remarks:—

"Notwithstanding the interesting aspects of these decolourisation processes, the authors maintain the opinion given above and add that they all have drawbacks, both for the extract manufacturer and the tanner; the first loses, whatever may be the process used, from 2 to 3 per cent. of tannin to the detriment of the yield in extract, and the percentage fails the second party, while the colour of his leathers is in no way altered. The authors can, in fact, affirm that, having had occasion to make important analysis of the tannin in different leathers, where they had used decolourised extracts (either by blood or by nitrate), all the leathers tanned by these extracts were darker than those yielded by other and well clarified extracts, and that although the colouration of a 1 per cent. solution was less dark than solution of purified extract. Moreover, the tannery of the future will be that which utilises mixed processes of tanning with extracts manufactured in a genuine manner and judiciously used; the opinion of Procter, the eminent English Chemist, is decisive on this point."

Mixed Extracts.

It is a well-known fact that in the tannery, the expert tanner does not work with any one single tanning material. He makes a judicious mixture of tanning materials of different colours, dark and light, to get his leather of the right colour. For example in India, the Babul (*Acacia arabica*) bark, which is decidedly the best tanning material, is never used alone as it gives leather of red colour, but it is mixed with myrabolans in suitable proportions for decolourising leather and rendering it suited to the employment of the most delicate shades of aniline dyes. In modern tanning, the use of bark has given place to tannin extracts of various descriptions, some of which are prepared from very deep coloured materials like Quebracho wood, malletto and Mangrove barks. The tendency has been, and still continues, to chemically decolourise these high coloured tannin extracts. But, as mentioned above, both the practical experience of the tanners and scientific research have shown that treated extracts give far from satisfactory results in the hands of the tanner. The experienced tanner, therefore, prefers to have pure extracts of tanning materials with which he is well acquainted and to use them to the best advantage by mixing them with other light coloured materials in his tannery. The interesting question, therefore, arises whether the future of the tannin extract industry does not lie in the manufacture of *mixed extracts.* In mixed extracts it will be only necessary to reduce them down to a standard colour, sufficiently light for the purposes of the tanner. For example, barks like those of Mangrove, *Shorea robusta, Terminalia tomentosa,* etc., occurring abundantly in India may well be mixed with myrabolams, leaves of the Rhus species, Babul pods, etc., and other abundant products of this country. Thus all sorts of tanning materials of different colours can be utilised for the manufacture of extracts of standard colour and strength. This procedure has the following advantages over the chemical treatment :—

(1) The percentage of tannin in mixed extracts is higher than in similar extracts treated chemically.

(2) The tanning properties of the original material suffer no deterioration in the mixed extracts.

(3) The colour of the extracts from the highly coloured materials can be reduced to the desired degree by altering the proportions of the ingredients to be mixed so as to produce, as

the expert tanner does in his tannery, an extract capable of yielding almost colourless leather.

(4) The serious defect in leather tanned by many tanning materials, *i.e.*, its harshness, can be successfully eliminated by mixing them with materials yielding soft tannage; in the case of chemical treatment, however, this defect becomes more pronounced.

(5) In the manufacture of mixed extracts, there are advantages peculiar to this country which are worth consideration. It is extremely difficult to procure cheap the fresh and pure chemicals required for the manufacture of tannin extracts, and it is inadvisable to stock them largely, since the chemicals used in this industry are liable to deterioration, and, further, by their use, the cost of production is considerably increased.

(6) In this and other tropical countries where there is a great abundance of tanning material of all kinds containing varying percentage of tannin, it is the manufacture of mixed extracts alone, which offers an outlet for their profitable exploitation. Instead of preparing extracts from materials poor in tannin on a large scale, as it is done in Europe, and placing such on the market by themselves, a procedure which could not be undertaken on a paying basis in India, extracts from a suitable admixture of materials of varying richness in tannin, and of varying degrees of colour, might well be prepared; with a mixture containing 20 to 30 per cent. of tannin, the process could be made to pay on a comparatively small scale. For example, it will not pay to prepare an extract on a small scale from a bark which has only 10 per cent. of tannin, but if 30 parts of this 10 per cent. bark and 70 parts of Mangrove barks (of 30 per cent. tannin) are mixed, we will obtain a mixture which would have on the whole a tannin content of about 24 per cent. and which will produce an extract of superior colour and value to that producible from Mangrove alone.

For the reasons given above, the writer is of opinion that the future of the tannin extract industry at least in tropical countries does not lie in chemical decolourisation of extracts but in the preparation of mixed extracts of standard colour and strength.

CHAPTER II.

Factors that determine the Quality of Tannin Extracts with special reference to Mangrove Bark Extract.

The quality of the tannin is chiefly determined by the following factors :—

(1) *The quality of the bark.*—The fresher and sounder the bark or the tan wood, the better is the quality of the resulting extract. If the bark is exposed for any length of time to atmospheric oxidation, the tannin contained in it is oxidized, resulting in a darker colour. Much of it becomes insoluble owing to the formation of insoluble products. Bark dried in the sun undergoes similar changes and its original percentage of tannin is considerably reduced. Mangrove bark when sun-dried becomes dark and hardened by the deposit of oxidation products in the fibre with the result that it yields its tannin with difficulty in the process of diffusion.

It is therefore necessary to always secure fresh bark for extraction.—This can only be possible if the central factory is situated close to the sources of supply; *if this is not feasible, the bark before despatch should always be air-dried in the shade and exposed in separate layers,* in well-ventilated sheds. This can be effected in commodious, airy store sheds erected specially for this purpose near the forests and equipped with wooden platforms in which to store bark until dry.[1] The bark when thus dried retains about 8 to 10 per cent. of moisture and is very much less liable to deterioration during transit to and storage in the central factory, than when freshly collected.

As regards the tan woods, the opinion of Messrs. Dumsney and Noyer (*Dumsney and Noyer loc. cit.*, page 128) may be cited. They urge upon the extract manufacturers to require of the suppliers of tan wood (chestnut wood), the delivery of sound wood and ask them to reject rotten and ferruginous wood as incapable of a normal yield of tannin. The effect

[1] See also Schlich's *Manual of Forestry,* Volume V (Forest Utilisation), pages 498 and 499.

of the rotting of the wood (or for matter of that of the bark), is to render insoluble a large proportion of the bodies originally soluble. They give the following analysis of the sound and the rotten chestnut wood which speaks for itself:—

	I		II	
	Sound wood.	Rotten wood.	Sound wood.	Rotten wood.
Soluble tannin . . .	7·40	2·80	6·10	3·40
Non-tannin . . .	1·90	1·10	1·50	1·00
Moisture	54·25	63·28	53·20	64·24

(2) *The quality of water.*—It is well known that mineral matters present in natural waters, when used for extraction of tanning materials, have an injurious effect on the colour and percentage of tannin in the resulting extract, on the colour more so, when the water is alkaline or when it has traces of iron in it. The loss of tannin is due to the formation of non-tannins and in some cases alkaline tannates. This process of decomposition of tannin set up by the mineral matter does not cease after the extracts have been prepared in the solid form. The saline matters even after extraction accentuate still further the loss already incurred during preparation, either by actually precipitating out the tannin by their contact or by inducing its conversion into non-tannin. In any case, the consequence is that the tannin extract prepared by saline waters will not only show loss of tannin during the process of manufacture, but will continue to do so even on storing.[1]

Besides this chemical decomposition, if the concentrated water remaining after evaporation is at all alkaline, it will darken and deepen the red colour of the extract made from mangrove barks. It may be pointed

[1] See note on "The transformations which are produced in the infusions of the tanning material" (when extracted by saline solutions) by *Ed. Nihoul* and *L. van de Putte* quoted by Messrs. Dumsney and Noyer (*loc. cit.*, page 141) and also on "The effect of the chlorides and sulphates of natural waters on the extraction of tanning substances," *Bull. Assoc. Bel. des Chimistes*, 1904, pages 115 to 123.

out here that the colour of tanning materials contained in the mangrove bark is extremely sensitive to alkalies.

The alkalis change the extract to deep dark red and the acids turn it into light yellow.

It is therefore essential that distilled water should be used in the treatment of all barks, and especially for the mangrove bark, which is particularly sensitive to alkales.

The addition of mineral or even of organic acids to neutralise the alkali contained in water is also very injurious, as the presence of these acids has the effect of precipitating most of the tannin out in the mangrove bark extract in the form of insoluble " reds."

Considering the sensitiveness of the mangrove tannin, the writer recommends that the distilled water to be used in its extraction should be previously made acid, not by the addition of any organic or mineral acids, but by passing it over some light coloured tannin contained in various available leaves and fruits.

(3) *Iron contact.*—Great care is to be exercised in avoiding the contact of tan liquors with iron in any shape, as this causes the blackening of the extract. One of the chief causes of the blackening of the Burma tannin extract has been the neglect of this precaution.

(4) The scales on the bark of mangrove are very hard and have a black fracture. They seem to contain the dark coloured end-oxidation products of mangrove tannin. It was also found that in the hollow spaces between the scales and the inner bark, a good deal of ferruginous dust is deposited through various agencies. This dust and the black material contained in the scales themselves, if permitted to enter the leaching vats, will exert a very injurious effect on the colour of the extract.

The mangrove bark should therefore be peeled and all earth brushed off its surface by means of copper wire brushes using a minimum quantity of water. The scales are of course to be rejected, and the bark thus cleaned should be immediately used.

Any neglect of these apparently small details results in lowering the quality of the extract to a great extent.

(5) The tan liquors should not be allowed to be exposed for any length of time to atmospheric action. *As soon as they are sufficiently concentrated they should be, as described in Chapter I, passed through refrigerators and then through decanting centrifugals to the vacuum pans.*

For cooling tan liquors, a supply of cold water say at about 15 to 18°C must be available in the factory, and this should be borne in mind in choosing the factory site.

(6) Heating of tan liquors for longer than is absolutely necessary is another factor which has a very detrimental effect in changing the composition of the extract owing to the formation of non-tannins and oxidation products. It will be seen from what has been given in Chapter I, that the Single Effect system of vacuum pans and even the Double and Triple effect systems, one after another, have been given up in favour of Kestner's evaporators, as improvements were effected in the machinery used in tannin extract according to the needs and experience of the manufacturers in Europe. In Kestner's evaporators of multiple effect the maximum of water is evaporated with the minimum of steam and in the minimum of time.

Of all the extracts, as has been pointed out, mangrove bark extract is the most sensitive and is liable to develop a dark colour through oxidation, heat and alkaline water, *it seems essential that the mangrove Tannin Extract Factory should be equipped with Kestner's evaporators of multiple effect.*

(7) Storing for any great length of time, even of good mangrove extracts, results in the reduction of their tannin strength. It is due to slow oxidation resulting in the formation of insoluble products. For example, the writer observed that mangrove extracts made at the Rangoon Tannin Factory in the year 1904-05 were reduced for the most part by 1910-11 to insoluble oxidized products of a blackish brown colour with dull earthy fracture. To take a recent example, the mangrove extract made in February 1911 showed a decrease of 3 per cent. of tannin after four months' storing. This rapid change in the percentage of tannin is possibly due to the presence of the mineral matter present in the natural water used for extraction, but it admits of little doubt that all tanning materials do deteriorate on storage.

For the reasons cited, *it is therefore advisable to secure a regular market for the fresh extracts as they come to hand and never to keep a large stock in the factory.*

CHAPTER III.

Defects of Extracts that have been experimentally manufactured in Burma.

Mangrove tannin extract has for some years been manufactured experimentally in Burma in fairly large quantities and has been put on the English market for valuation. A summary of trade objections against the extracts thus made may appropriately be given here.

The Burma extract is much richer in tannin than the Borneo Cutch which is the best brand of Mangrove extract on the market and is evidently made from barks somewhat poorer in tannin than the Burma barks, but this higher percentage of tannin is nullified by an excessive amount of colour. Another great objection was the excess of moisture in the Burma extract on account of which it became "mouldy" being white and apparently perished on the top. It tanned harsh, giving dark leather. It had large amount of insoluble matter which was the general objection.

The chief cause of these defects in the extract have now been traced to the alkaline and saline nature of the water used in the preparation of the samples. The water used coming from an artesian well, when concentrated to a small bulk gave a distinct alkaline reaction. Its saline nature is evident from the following analysis :—

Total alkali	·044 grm. per litre (in terms of Na_2CO_3). ·0416 grm. per litre (in terms of $CaCO_3$).
Total chlorine	·0381 grm. of chlorine per litre (·063 grm. of NaCl per litre).
Total mineral matter . . .	·152 grm. per litre.

The qualitative tests showed the presence of sodium, calcium, chlorine, carbon dioxide and sulphates.

The colour of the extract and the percentage of the insolubles in it cannot be controlled unless the extract is manufactured with distilled water and under better conditions of refrigeration.

After the extract leaves the vacuum pans, it has to be further dried otherwise the percentage of moisture remains too high.

In order to dry the extract there should be a shed having a large floor covered with canvas, or in place of canvas, boxes of uniform size about 1″ deep might be made to receive the wet extract, which should then be allowed to dry by keeping the boxes on a system of shelves specially constructed.

About 18 tons of Mangrove tannin extract was experimentally prepared in February 1911 by admixing myrabolams with Mangrove barks in the proportion of 1 : 6 previous to extraction in order to counterbalance the disadvantage of the alkalinity of water used.

The following table gives the percentage composition of an average sample taken out of the bulk according to different chemists :—

The Analyses of an average Sample out of a lot

Description of Sample.	Moisture.	Ash.	Inso-luble.	Total soluble solids.	Non-tannin.	Tannin.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Mixed extract prepared by extracting a mixture of the bark of *Rhizophora mucronata* and myrabolams in proportion of 6 : 1 on the air-dried material.	23·00	...	2·4	74·6	13·5	61·1
	21·5	...	0·8	77·7	13·3	64·4
	14·3	...	5·7	80·0	18·0	62·0
	17·6	...	6·1	76·3	15·6	60·7
	13·43	...	3·72	82·85	19·54	63·31
	20·8	1·5	...	78·4	12·3	66·1
	15·00	...	2·5	82·5	10·75	71·75
	13·43	...	...	85·8	15·6	70·20

of 18 tons of Mangrove and Myrabolam Extract.

Tannin on the dry material.	By whom reported.	Tintometer colour measurement on solution of ·5 per cent. in 1 cm. cell.		REMARKS.
Per cent.		Red.	Yellow.	
79·35	Professor Procter .	26·9	45·6	Professor Procter remarks that the extract is good in strength but the colour seems somewhat darker, especially in yellow than the commercial ones. This is no doubt due to darkening in concentration.
81·52	Dr. Gordon Parker to Forest Chemist.	24·2	35·8	
72·34	Dr. Gordon Parker to Messrs. Rink Bros., London.	17·0	33·0	
73·66	MacArthur & Co.	...	...	
73·13	Messrs. Finlay, Fleming & Co.	16·9	25·4	
83·45	Professor Dunstan .	29·3	24·6	
84·41	Puran Singh (Forest Chemist).	...	...	Analysed in February 1911 before packing and sending it to England for valuation.
81·09	Ditto .	...	...	Analysed again in June 1911.

It will be seen that the colour still remained high in spite of the addition of myrabolams which should have considerably reduced the colour of the resulting extract, the red varying from 17 to 29 and yellow from 25 to 46, while in good extracts, in order to meet market requirements, the red should not exceed 10. This is mainly due to the bad quality of the water used. As pointed out elsewhere, the colour can be reduced by using distilled water even without the addition of myrabolams to the required standard. This fact has been fully supported by small scale experiments conducted in the Laboratory. In other respects, the extract has been pronounced by competent authorities to be fairly good, as will be seen from the following letter from Professor Dunstan of the Imperial Institute, London, addressed to the Forest Chemist:—

Letter from Professor Dunstan of the Imperial Institute, London, to the Forest Chemist, dated 28th April 1911.

"The sample consisted of a solid, brittle, dark brown extract, showing a vitreous fracture. This extract was almost completely soluble in cold water * * *

The extract produced a reddish brown leather of fairly stiff texture.

This sample of mangrove extract is the best yet received from India for examination at the Imperial Institute. It is of good consistency and appearance, does not contain excess of moisture, is almost completely soluble in cold water, and is very rich in tannin. The percentage of tannin present is higher than samples of Borneo mangrove extract at the Imperial Institute, but the extract furnishes a rather darker and redder leather than that yielded by good mangrove extract from Borneo."

It may be safely stated that the tannin extract made from Burma Mangrove barks under the better conditions described in Chapters I and II, will be equal to the Borneo Cutch and would command as ready a sale. The eighteen tons of extract mentioned above, though not quite so good, was valued at £12-6*s*. per ton c. i. f., Glasgow. The quality of the pure Mangrove tannin extract would then come up to that of this mixed extract with sufficient improvement in its colour, but according to the experiments recently carried out the results will be far better if myrabolams were mixed with Mangrove bark in the proportion of 1 : 7 previous to extraction. This admixture would not only improve the colour but eliminate the rather serious defect of harsh tannage on the resulting extract, giving softer and lighter leather.

In conclusion it may be remarked here that a typical tannin extract factory must be equipped with an up-to-date machinery capable of treating 60 tons of raw materials per day. The erection of such a factory

would, calculated from the estimates given by Messrs. Dumesny and Noyer, require a capital of R2,86,000.

It goes without saying that the larger the scale of manufacture, the greater is the economy effected in the cost of production. There are tannin factories in Europe dealing with from 10 tons to 120 tons of chestnut wood per 24 hours paying in the case of a 60-ton factory 30—33 per cent. of profit on the capital outlay, although this wood contains only some 8 per cent. of tannin. In this case, however, no heavy freight charges have to be paid as the factories are near the centres of consumption.

CHAPTER IV.

The Barks of Mangrove Species considered as raw materials for Tannin Extract manufacture.

This chapter deals with the percentage yield of the tannin extract from the various mangrove barks.

The following table gives the analyses of mangrove barks, which have been recorded from time to time :—

Serial number.	Species and Locality.	Moisture.	Tannin.	Tannin on dry material.	By whom reported.	REMARKS.
		Per cent.	Per cent.	Per cent.		
1	Fresh bark of *Rhizophora mucronata* (from Tavoy) . .	...	...	50	Dr. Hunter of Rangoon College.	Analysed by Lowenthal's method.
2	Dry bark of *Rhizophora mucronata* (from Tavoy) . .	...	...	45	Ditto	Ditto.
3	Dry bark of *Rhizophora mucronata* (from Bassein) .	...	...	20	Ditto	Ditto.
4	Bark of *Rhizophora mucronata* (locality not known) . .	14·22	...	27·29	Professor Dunstan.	
5	Ditto ditto .	13·17	...	4·13		
6	Ditto ditto .	8·70	5·0	5·8		
7	Ditto ditto .	10·90	26·90	29·50	Mr. D. Hooper.	
8	Ditto ditto .	...	...	19·47	Dr. Leather (in 1898).	
9	Ditto ditto .	Air-dried	...	28·85	Staiger.	
10	Ditto ditto .	Do.	...	25·10	Hunt and Mackay.	
11	Ditto ditto .	Steam dried	...	29·22		

Serial number.	Species and Locality.	Moisture.	Tannin.	Tannin on dry material.	By whom reported.	REMARKS.
		Per cent.	Per cent.	Per cent.		
12	*Rhizophora gymnorhiza* (from Bengal)	14·14	...	12·77	Professor Dunstan.	
13	Ditto ditto .	9·60	15·90	17·50	Mr. D. Hooper.	
14	Ditto ditto .	...	14·81	...	Dr. Leather.	
15	*Carrallia integerrima* (from Pegu) .	...	...	1·5	......	The ash is equal to 15·2 per cent. and the bark was about ½ inch thick.
16	*Ceriops Candolleana* (from Singapur) .	13·34	20·00	23·07	Professor Trimble (in 1897).	Ash 10·60. *Tengah* bark from Singapur and *Bakan* bark from Borneo are referred to this tree and are made into extracts (Kew Bulletin, 1897).
17	*Ceriops Candolleana* (from Bengal) .	13·70	27·24	31·56		Ash 5·83
18	Ditto ditto .	13·30	26·20	30·20	Mr. D. Hooper (1898).	Ash 10·60
19	Ditto ditto	15·40	15·50	18·30		Ash 13·70
20	Ditto ditto .	...	18·78	...	Dr. Leather (1899)	
21	Ditto ditto .	14·47	...	17·77	Professor Dunstan (1900).	
22	Ditto ditto	12·32	...	21·54		
23	Ditto ditto .	17·18	...	13·23		
24	*Ceriops Roxburghiana* (Sunderbuns, Bengal) . .	12·14	...	25·34	Professor Dunstan.	
25	Ditto ditto .	9·2	19·20	21·10	Mr. D. Hooper.	
26	*Kandelia Rheedii* (Sunderbuns, Bengal) . . .	14·29	...	11·99	Professor Dunstan.	

Serial number.	Species and Locality.	Moisture.	Tannin.	Tannin on dry material.	By whom reported.	REMARKS.
		Per cent.	Per cent.	Per cent.		
27	*Kandelia Rheedii* (Sunderbuns, Bengal)	9·90	12 20	13·40	Mr. D. Hooper.	
28	Ditto ditto .	...	14·54	...	Dr. Leather.	
29	Ditto ditto .	...	...	20·4	Mr. D. Hooper.	
30	Do. from Malabar Coast (very thick, reddish and dense) . . .	...	...	27·4	Ditto.	

Commenting on the analyses made at the Imperial Institute of London by himself as given in the above table, Professor Dunstan says:—"These results show that many of these barks are very rich in tannin, notably one specimen of *Rhizophora mucronata,* which contains over 27 per cent., although the second specimen of the same bark contains only 4 per cent. It is desirable that further samples, of known origin and age, of *Rhizophora* bark should be sent for examination so that the cause of the great discrepancy between the percentage of tannin in these two samples may be cleared up. * * * * * *
The bark of *Ceriops Roxburghiana,* of which only one sample was submitted, is also rich in tannin, containing 23·5 per cent. Considerable variation is shown in the percentage yielded by the three specimens of *Ceriops Candolleana,* namely, 13, 17 and 21. The lowest percentages of tannin are furnished by the two barks of *Bruguiera*[1] *gymnorhiza* and *Kandelia Rheedii,* namely, 12·7 and 11·9, but here only one sample of these barks was sent. *

It is evident from the results recorded above that there is considerable variation in composition in different samples of one and the same bark, which points to the desirability of collecting these barks systematically at different stages of growth so that it may be ascertained by chemical analysis when the tanning value reaches its maximum."[2]

[1] Also termed *Rhizophora.*

[2] Technical Reports and Scientific Papers, Imperial Institute, 1903.

Through the kindness of Mr. C. Rogers, Conservator of Forests, Pegu Circle, Rangoon, eight specimens of mangrove barks obtained from old and young trees of the same species were examined for comparison of colour and tannin strength. The samples were collected and despatched by the Divisional Forest Officer, Andaman Isles, in a fresh and moist condition packed in gunny bags. Some portions of them were completely rotten when they arrived. The rotten portions were rejected and the sound bark was picked out and analysed. The following table gives the results of the examination of these, along with one specimen of mangrove bark drawn from old trees (locality unknown), which had been lying in the laboratory stores for about two years, for purposes of comparison :—

Analysis of fresh Mangrove Bark from Andamans.

Serial number.	Description.	Moisture on fresh bark.	Moisture on air-dried bark.	Ash.	Total soluble solids.	Non-tannin.	Tannin.	Colour measurement on ·5 solution in 1 cm. cell.		The yield of extract calculated on air-dried material, with 20 per cent. moisture from 100 parts of the bark.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Red.	Yellow.	
1	*Rhizophora mucronata* bark (from old trees)	40·51	8·84	6·64	45·88	8·01	37·87	13	39	65·88
2	*Rhizophora mucronata* bark (from young trees) . .	48·05	7·43	8·68	31·92	7·83	24·09	20	57	51·92
3	*Rhizophora mucronata* bark stored in the laboratory for about two years (from old trees)	11·17	10·31	8·34	32·12	8·7	23·42	22	58	52·12
4	*Rhizophora conjugata* bark (from old trees)	47·77	8 47	17·46	44·40	9·62	34·78	9	22	64·40

Analysis of fresh Mangrove bark from Andamans—*contd.*

Serial number.	Description.	Moisture on fresh bark.	Moisture on air-dried bark.	Ash.	Total soluble solids.	Non-tannin.	Tannin.	Colour measurement on ·5 solution in 1 cm. cell.		The yield of extract calculated on air-dried material, with 20 per cent. moisture from 100 parts of the bark.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Red.	Yellow.	
5	*Rhizophora conjugata* bark (from young trees) . .	41·2	8·34	11·14	40·00	12·26	27·74	9	16	60·00
6	*Bruguiera gymnorhiza* bark (from old trees)	45·73	9·24	7·13	45·48	8·2	37·28	9	22	65·48
7	*Bruguiera gymnorhiza* bark (from young trees) . .	47·32	8·35	15·09	40·72	10·09	30·63	8	22	60·72
8	*Ceriops Candolleana* bark (from old trees)	38·61	8·2	5·6	45·56	12·16	33·40	12	42	65·56
9	*Ceriops Candolleana* bark (from young trees) . .	40·14	7·95	9·19	33·80	8·31	25·49	15	50	53·80

It will be seen from the above table, that once the bark is air-dried, its moisture content becomes almost constant. The fresh bark received from Andamans had 38 to 48 per cent. of moisture, while the same, air-dried, gave 7 to 9 per cent., and the bark stored for two years in the laboratory gave 10--11 per cent. of moisture, losing only 1 per cent. when its coarse powder was air-dried. The ash in the above samples ranges between 5 and 17 per cent. The young bark of all species shows more ash than the old, in some cases almost double. Of these species *Rhizophora mucronata* and *Ceriops Candolleana* show the lowest percentage of ash, while *Rhizophora conjugata* gives the highest.

The tannin values of these barks range between 24 and 37. These have been carefully determined not only by the hide powder process, but by the nickel hydroxide process, the figures obtained by which are in close agreement with those given in the table.

It is rather difficult to determine the colour measurements with absolute accuracy. But the observations recorded in the above table were made under similar conditions and the figures may, therefore, be taken as approximately correct. They are not of much assistance in enabling any nice distinctions to be drawn between the colour of the old and the young bark, but they clearly show that the extracts from the bark of *Rhizophora mucronata,* whether old or young, and those from *Ceriops Candolleana* would give extracts of deeper colour than those of *Rhizophora conjugata* and *Bruguiera gymnorhiza* barks, whether old or young.

Yield of Extract per 100 parts of Bark.

The above table shows that the mangrove barks when air-dried, containing 8 to 10 per cent. of moisture, yield 50 per cent. of extract, containing 20 per cent. of moisture.

A lower yield than this shows that either leaching is not thoroughly done or the quality of the bark is below the standard.

From fresh bark containing 40 per cent. of moisture, the yield of the extract with 20 per cent. water will be ⅓rd of the total quantity of the bark used.

CHAPTER V.

The Estimates of Profit and Loss of the manufacture of Mangrove Tannin Extract in Burma.

Before considering the estimates of profit and loss of this industry, it seems desirable to give a general idea of the conditions under which it should be started.

The Raw Material.—The raw material is fairly abundant in Tavoy, Mergui and Andaman Isles. If the Mangrove forests are worked in scientific manner, the supply may be said to be almost inexhaustible. The current market rate of the Mangrove bark which is also generally used by Burmese tanners, is about R22 per ton at Rangoon. Its cost at Mergui is R15 per ton, the freight from Mergui to Rangoon being R5 per not. But the price of the Mangrove bark is liable to considerable

reduction if regular and large supplies are contracted for, or if the collection is methodically undertaken by the manufacturer direct. The wholesale cost at Mergui is R15 per ton, and it stands to reason that at this rate the dealer must be making some profit after allowing for transport of the bark from the forest to the market. Though exact figures at which the bark can be extracted are not known, the total cost of the collection of bark per ton by direct agency may be safely placed at not more than R10 per ton, which would work out to about R15 per ton delivered at a factory near Rangoon. Besides it has been noticed that the bark merchant sells his dry and fresh bark at the same rates. Hence a further reduction seems possible were the manufacturer to have his own drying sheds in the forests and were the material to be air-dried before shipping. Taking the moisture of fresh bark to be 50 per cent, the cost of the freight per ton is reduced at once by half, and the total cost is thus reduced from R15 to R12-8 per ton delivered in the vicinity of Rangoon.

If the bark is to be at all purchased in the open market, it must be done on its percentage contents of tannin and moisture. The Mangrove barks vary much in quality, and it would be unbusiness-like to pay for good as well as for bad barks at the same rate. The price of ir-dried bark containing about 30 per cent. of tannin with a moisture content of 10 per cent. say, might be fixed at the maximum of R20 per ton delivered at the factory.

The Locality.—Rangoon, however suitable in other respects, is not an ideal place for a tannin factory, the successful working of which depends on the cheapness and the good quality of the bark. It should be established as close to the Mangrove forests as may be feasible. Mergui would be a much better site. The bark from Andamans can also be brought there. The price of the raw material would of itself fall to R15 per ton even if the bark is purchased in the open market, and as said above, it is possible to reduce it still further if the factory collects it by its own agency.

Another apparent advantage will be its proximity to the sources of the supply of fuel. There is no reason why the wood of this Mangrove after the bark has been removed should not be used as fuel. The supply of fuel of other kinds also is abundant and cheap at Mergui.

The Yield of the Extract.—It has already been shown that Mangrove barks of good quality should at least yield 50 per cent. of solid extract

containing 20 per cent. of moisture. For purposes of estimate, however, the ratio of bark to extract is taken at 2·6 : 1 instead of 2 : 1, thus allowing for the variation in the quality of the bark.

The Working of the Factory.—The tannin factory should be worked day and night.

The following rough estimate of the capital outlay on a model tannin factory capable of dealing with 60 tons of bark or tan woods in 24 hours is adopted from the original estimates of Messrs. Dumsney and Noyer, Chemical Engineers of France, as given in their Wood Products Distillates and Extracts.

The total outlay is estimated at R2,86,500, as follows:—

		R
I.	Battery of wooden vats. The battery of 16 wooden vats of 4,400 gallons capacity	39,000
II.	Two cutters with angular boss, capable of reducing 30 metric tons of wood into chips in 12 hours	4,700
III.	Two elevators and one conveyer	3,000
IV.	Steam engine 50-70 H. P.	7,200
V.	Boilers, 120 sq. ft. heating surface	18,000
VI.	Two gas generating furnaces	3,600
VII.	Triple Effect evaporating plant (capacity 770 gallons evaporated per hour)	48,000
VIII.	Four decanting turbines with an output of 220 gallons (Rebatl, Buffand & Co.'s system)	9,600
IX.	Factory buildings (including shed, stores)	27,000
X.	Site for the building with a water supply of 11,000 gallons per hour	7,200
XI.	Water works	4,800
XII.	Five refrigerators	4,800
XIII.	Vats for liquors	2,400
XIV.	Office and laboratory	1,200
XV.	Noyer's condensor-re-heater reservoir	2,400
XVI.	Shafting and pullies	1,200
XVII.	Incidentals for casks, weighing machines and equipment	2,400
XVIII.	Running capital	1,00,000
	GRAND TOTAL	2,86,500

An estimate of the profit on preparing 9,000 tons of mixed extract of Mangrove and Myrabolam in proportion of 6: 1, the calculated output of the factory, is attached :—

Dr.	R	*Cr.*	R
Cost of 20,057 tons of Mangrove bark at R20 a ton	4,01,140	The sale price of 9,000 tons at £12 per ton .	16,20,000
Cost of 3,343 tons of myrabolams at R70 per ton	2,34,010	Deduct sale commissions at 10% . .	1,62,000
Coal	1,00,800		
Labour	45,000		
Stores	7,000		
Packing in boxes	60,750		
Superior Establishment	1,00,000		
Repairs and Depreciation at R10 % on Machinery and buildings . . .	18,600		
Interest on the capital outlay of 2,86,500 at R6 %	17,160		
Other charges at R10 % of the total expenditure detailed above . .	1,25,460		
Freight on 9,000 tons of extract at R30 per ton to England	2,70,000		
Total .	13,79,920		
Balance as Profit	78,080		
Grand Total .	14,58,000	...	14,58,000

Thus in the manufacture of mixed extracts of good quality there is all likelihood of a profit of 27 per cent on the capital outlay.

Messrs. Dumsney and Noyer show a profit of 30—33 per cent. on the capital outlay of R2,10,000 when dealing with chestnut wood containing 8 per cent. tannin. This estimate is applicable to tan woods of India and Burma having a similar percentage of tannin.

In the case of a small concern with a minimum output of 1½ tons of extract per 24 hours, it has been found by the writer, based on his actual experiments that the capital outlay required will be R1,00,000, yielding a net profit of R16,000 per year, or 16 per cent.

If, however, the raw material used is poor in tannin it will be very difficult to make such a concern remunerative.

The estimates given above are only provisional and the actual figures may vary according to the fluctuation of the market of tannin extracts and according to the care, expert knowledge and strict economy that may be brought to bear upon the working of such a concern.

APPENDIX A.

The Development of Trade in Tannin Extracts.

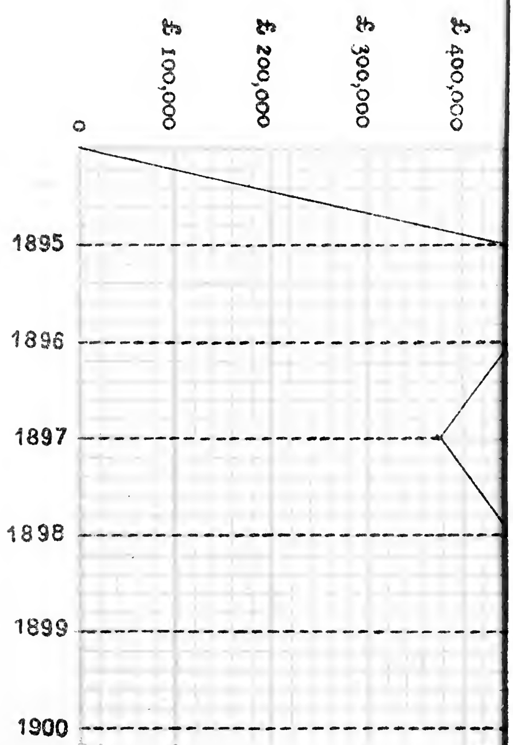
The old method of tanning by tan barks is being very rapidly replaced by tanning with tannin extracts. The total French production of extracts including that of Corsica reached in 1904 to about 105,000 tons worth about £1,040,000. In the same year France imported 1,841 tons and exported 49,707 tons of tannin extracts. The German Empire imported 11,005 tons of Quebracho and 27,921 tons of other extracts in the year 1904 and 13,655 tons of the former and 32,603 tons of the latter in the year 1905.

The 617 tanneries of the United States consumed in the year 1906 147,049 tons of tannin extract (in addition to 1,224,412 tons of the tan barks), while in the year 1900, the consumption of the extracts was only 14,293 tons. *Capital* of the 23rd April 1908 writes: "In the United Kingdom for 1906, extracts represent $\frac{7}{16}$ of the total imports, and private advices declare that for 1907, extracts have already exceeded all other agents by over 20 per cent. In America, extracts represent $\frac{1}{4}$ of the total production of tanning agents. In Germany for 1906, the proportion of extracts to the whole is a fraction less than 25 per cent., but there are prohibitive conditions attaching to the use of extracts in Germany other than the home made article, which effectively prevent the cultivation of improved methods of manufacture or further expansion of the industry."

Statistics of the imports of tannin extracts in the United Kingdom have been kindly supplied by the Secretary, Chamber of Commerce, London, and are shown on Plate IV.

The demand made on bark and tan woods for extraction and for tanning purposes by factories in Europe and America is indeed so enormous that fears are entertained of the shortage, at no distant date, of the raw material in the forests that are being indiscriminately destroyed in those countries to meet the world's demand for tannin extracts. To take an example, in France including Corsica, Italy and Spain, there are 26 tannin extract factories (this figure is for the year 1903) with their

Puran Singh.—Note on Mangrove Tannin



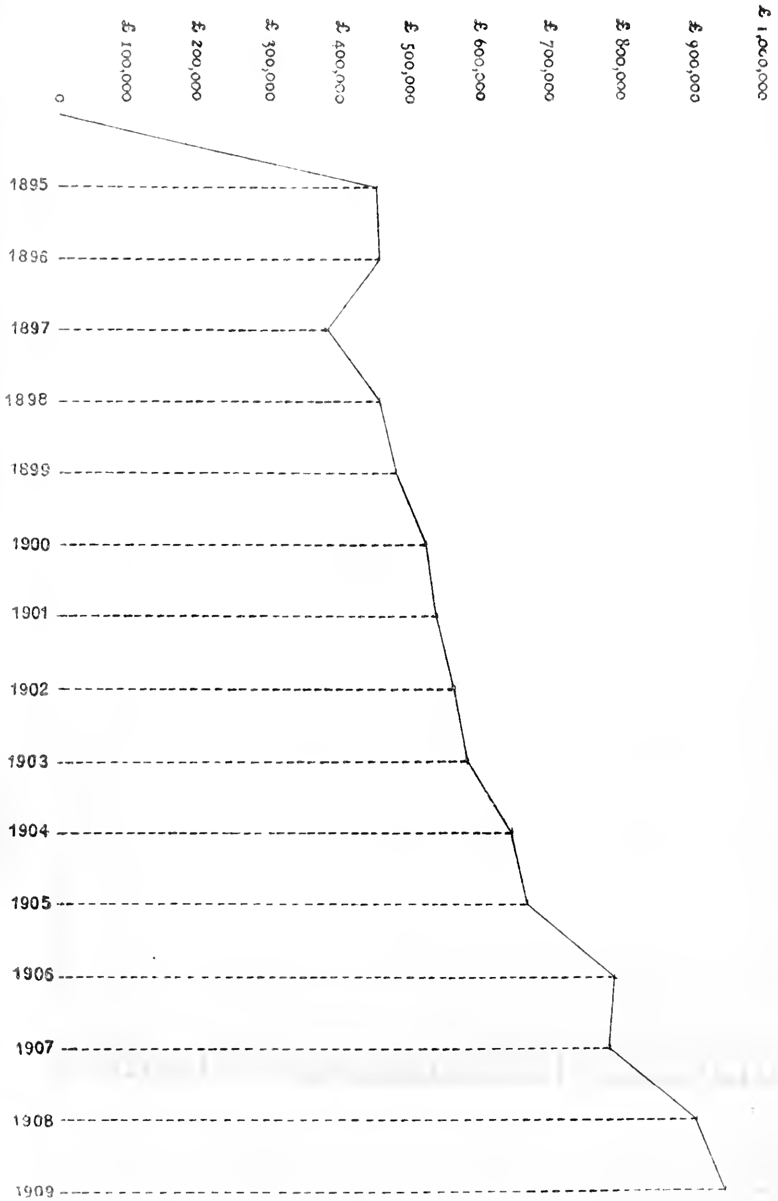


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Photo.-Mechl. and Litho. Dept., Thomason College, Roorkee.

Zinco., November, 1911.—No. 8429-3-1100.

number yearly increasing, which are reported to consume 450,000 metric tons of chestnut wood. Taking 40 trees to an acre, yielding 150 tons of wood, it has been calculated that the consumption of chestnut wood by the above-mentioned factories represents the disappearance of 3,000 acres of chestnut trees annually. In fact at certain places the supply of raw materials is already running short. For instance, it is stated that Corsican disafforestation will before long compel certain tannin factories to engage in the sugar industries (which, it may be noted, can be carried on by the same machinery as is employed for the preparation of tannin extracts), and already beetroot experiments have been organised near Bastia.

The forests of India, the Straits Settlements and other tropical countries are, as it is well known, extremely rich in tanning materials. If they are judiciously worked by a system of rotation so as to permit of a sustained yield, these forests may be said to be capable of yielding a practically inexhaustible supply. The exploitation of tanning materials in Burma and India consequently opens up vast possibilities.

In conclusion, it may be pointed out that in this industry Europe and America cannot be said to be so far ahead of India as they are in other chemical and mechanical industries.

It is doubtful whether the chemistry of tannin has yet been properly investigated or understood, and with its large supplies of raw material, and with an extended knowledge resulting from experimental work for which there is much scope, India and the East may well be regarded as the land of promise for the manufacture of tannin extracts.

APPENDIX B.

The following firms may be consulted for tannin extract machinery:—

(1) Blair, Campbell & McLean, Ltd., Govan, Glasgow.

(2) Buffaud & Co., Lyons, France.

(3) Messrs. John Miller, Glasgow.

(4) Messrs. Huxum and Browns of Exeter, England.

(5) W. J. Fraser & Co., Ltd., London.

(6) 181, Queen Victoria Street, London, for Kestner Evaporators.

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Note on the Preparation of Tannin Extracts

With special reference to those prepared from the bark of Mangrove (*Rhizophora mucronata*)

BY
PURAN SINGH, F.C.S.,
Chemist at the Forest Research Institute, Dehra Dun, India.

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